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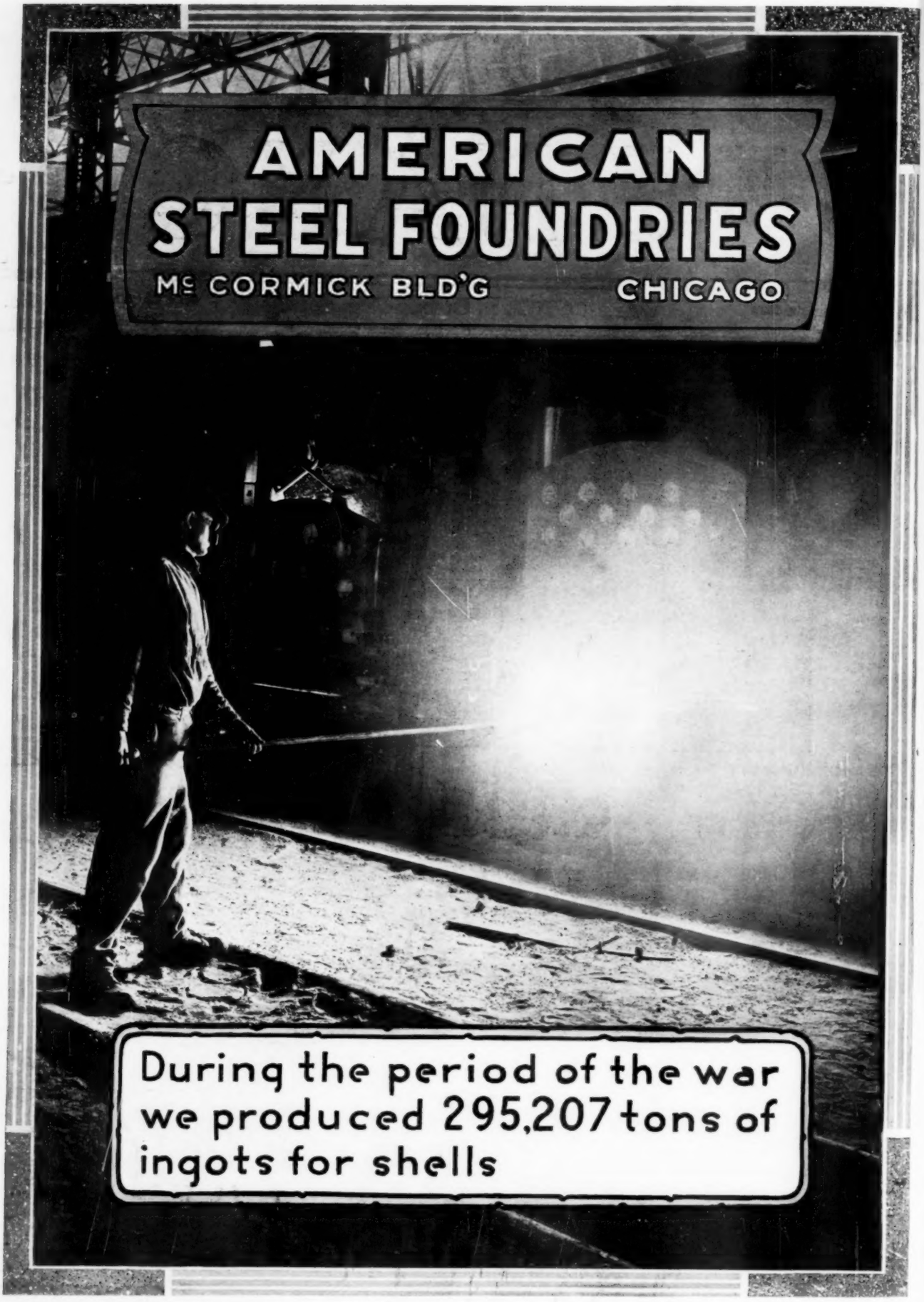
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THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

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The Ammunition Problem

By

J. H. BURNS

Member A. O. A.

ONE of the principal lessons which the World War has emphasized is that at the present time the military force of a nation is directly applied against the enemy almost entirely through the medium of chemical ammunition. By chemical ammunition is meant all kinds of ammunition which are able to cause damage through the aid of chemical reactions. The Field Artillery *has no other means of damaging the enemy* than the force contained in the flying projectile of one kind or another, filled with explosive or gas, which the gunner shoots from his cannon. The same is true for the Infantry and Cavalry, except in the case of hand-to-hand conflicts. It is likewise true for the Navy.

It follows, therefore, that unless a country makes proper arrangements for an adequate supply of the most powerful ammunition its engineering ability is able to produce, it can never utilize its full potential strength against the enemy. It is believed to be of value to summarize very briefly the history of the development of ammunition in order to ascertain its present status and future possibilities.

As we trace the history of man we find that in his efforts to solve his most pressing problems, he has always endeavored to put to his use, in constantly increasing quantities, the forces and materials of nature. His ability to do so is the true measure of his scientific development. It is what has made him the master of all the animals that inhabit the world. And the fact that, in general, man's most pressing problem has been war, means that war is in great measure responsible for his scientific development.

In his earliest days he was able to use only clubs and stones, or materials requiring a minimum of change. These are still the natural ammunition of man. Centuries later, with the coming of the iron age, he applied this development to ammunition, producing the spear and the battle-ax, etc. But these could be effective only within throwing distance and in order to increase his range he invented the sling, the bow and arrow, etc.

These simple types of ammunition represent man's development over many centuries of human progress and were his weapons only a few centuries ago even in the nations with the most advanced civilization. Up to this stage in the world's progress, therefore, the conduct of war, with the aim of being able to utilize the maximum offensive strength of the nation, required only that the man power of the nation be well organized, trained, and initially equipped. The problem of munitions supply was easily solved, for the consumption thereof was negligible.

Powder Charge and Projectile for 16-inch Gun

No further material progress occurred until mankind broke into the realm of chemistry. The general evidence is that the alchemists of the 8th century discovered a mixture of materials that would burn with such speed that the burning was practically an explosion. This was the forerunner of black or gunpowder. Some four centuries later, or about 1250, the discovery had been applied to munitions and the chemical force harnessed to hurl projectiles of one kind or another against the enemy. For 600 years, or from 1250 to 1875, black powder continued as practically the sole representative of chemistry in warfare and all efforts were towards its more efficient utilization.

From 1875 to the present date the application of chemistry to munitions has expanded rapidly. During this time chemical knowledge has so well advanced as to allow of the nitrification and conversion of various bases, such as cotton, toluol, etc., into powders or explosives. In 1886, or only 36 years ago, smokeless powder was invented and made applicable to use in firearms and it is since that time TNT, ammunition picrate. etc., have been combined with our munitions programs.

During this latter period also great advances have been made in metallurgy which permit the metals to withstand very heavy stresses and make them much more useful in ammunition. Mechanical and chemical engineering have likewise advanced at a very rapid rate and the knowledge gained thereby has been utilized for incorporating in our ammunition designs the discoveries in chemistry and metallurgy, and for producing such designs in ever increasing quantities.

The rapidity with which the consumption of ammunition has grown in recent years is shown in the accompanying three tables: Rates of Artillery Fire Per Gun Per Day in

Recent Wars, Expenditure of Artillery Ammunition in Modern Battles, and Expenditure of Artillery Ammunition in Recent Wars. While these tables speak for themselves, it is worthy of note that in the battle of the Somme in 1916 the British Forces expended over 120 times as much artillery ammunition as was expended by the Union Army during the battle of Gettysburg. The average *monthly* expenditure of artillery ammunition of the British and French Forces during 1916 was over two and one-half times the total expenditure of artillery ammunition by all of the Union Forces during the entire Civil War, and a comparison with other wars produces a more overwhelming relationship. But great as these figures are, they do not tell the whole story, for the ammunition of the World War was on the average much greater in strength per round than was the ammunition of preceding wars.

RATES OF ARTILLERY FIRE PER GUN PER DAY IN RECENT WARS

War	Army	Approximate rounds per gun per day
1854-56, Crimean	Brit. & Fr.	5*
1859, Italian	Austrian	.3
1861-65, Civil	Union	4
1866, Austro-Prussian	Austrian	2.2
	Prussian	.8
1870-71, Franco-Prussian	German	1.1**
1904-05, Russo-Japanese	Russian	4
1912-13, Balkan	Bulgarian	7
World War		
September, 1914	French	8**
Jan. 1 to Oct. 1, 1918	Italian	8**
Jan. 1 to Nov. 11, 1918	United States	30**
Jan. 1 to Nov. 11, 1918	French	34**
Jan. 1 to Nov. 11, 1918	British	35**

*Siege of Sebastopol **Field gun ammunition only.

Money expenditures establish a reasonable comparison of the importance of various activities. The following table shows "Expenditures by Army Bureaus" during the World War:

		Per ct.
Quartermaster Corps:		
Pay of the Army, Etc.	$1,831,273,000	12.9
Other Quartermaster Corps appropriations	6,242,745,000	43.8
Ordnance Department	4,087,347,000	28.7
Air Service	859,291,000	6.0
Engineer Corps	638,974,000	4.5
Medical Department	314,544,000	2.2
Signal Corps	128,920,000	.9
Chemical Warfare Service	83,299,000	.6
Provost Marshal General	* 24,301,000	.17
Secretary's Office and miscellaneous	* 33,367,000	.23
Total	$14,244,061,000	100

* Figures for December 31, 1918. Expenditures since that date for these purposes have been small compared with other items in table.

And of the money expended by the Ordnance Department, some two-thirds were for ammunition. The Diagram—"Where the Army Dollar Went," shows the relationship of the expenditures for munitions and ammunition to those for other purposes.

These records surely indicate that the problem of ammunition supply is now one of the major tasks of war and that its importance in future wars will be even greater. In most general terms, the ammunition problem is to supply our armies when mobilized with ammunition of satisfactory quality and quantity at minimum cost to the United States.

Quality demands that ammunition be of uniform and proven character, that it be capable of being manufactured in large quantities, and that it have incorporated in it at least the reasonably up-to-date developments in chemistry, metallurgy and engineering.

Quantity demands that stocks and procuring arrangements be such as to insure a proper supply of ammunition to our troops at the time and place required.

General Solution of the Ammunition Problem.

The solution is dependent upon a well trained and continuing personnel constantly at work on the problems; a comprehensive arsenal and schooling system for the development of the art and the instruction of officers, soldiers and employees; and especially a more clearly defined munitions and ammunition policy that is satisfactory to the higher military authorities in the Executive Department of the Government and has the continuing support of Congress.

Personnel: This is the basis of the solution of all human problems; and it is axiomatic that the larger and more difficult the problem, the greater should be the number and ability of the persons endeavoring to solve it. It is believed that

EXPENDITURE OF ARTILLERY AMMUNITION IN MODERN BATTLES

Year	Battle	Days' duration	Army	Rounds of artillery ammunition expended
1863	Chickamauga	2	Union	7,325
1863	Gettysburg	3	Union	32,781
1870	St. Privat	1	German	39,000
1904	Nan Shan	1	Japanese	34,047
1904	Liao Yang	9	Russian	134,400
1904	Sha Ho	9	Russian	274,360
1915	Neuve Chapelle	3[a]	British	197,000
1915	Souchez	1[b]	French	300,000
1916	Somme	7[c]	British	4,000,000
1917	Messines Ridge	7[c]	British	2,753,000
1918	St. Mihiel	4[b]	U. S.	1,093,217

Artillery preparation lasted: *a.* 35 minutes. *b.* 4 hours. *c.* Intermittent 7 days.

ammunition has been neglected badly in the past, not only by the makers of ammunition or the Ordnance Department, but also by the users of ammunition or the line of the army and by the controlling officers of the War Department. We can only constantly strive to get more and better personnel engaged in the ammunition problem if we would keep it well solved.

Arsenal System: Prior to the World War the efforts of the Ordnance Department in ammunition development were divided between two arsenals. As a consequence when the war broke out, the forces trained at each arsenal thought only of the work that was being done at their arsenal and not of the whole subject or complete rounds of ammunition. As a result of this, many important matters were overlooked, with consequent loss of time, effort, and money. Since the war, the Ordnance Department, with the approval of the War Department and Congress, has concentrated at Picatinny Arsenal, Dover, New Jersey, all its efforts in the development of artillery ammunition, including fuzes, powder and explosives, shell and shrapnel, and the complete assembly thereof. The arsenal is only in its infancy, however, as an Ammunition Development Arsenal, and will have to be favored by Congress and the War Department for several years if we would have the ammunition development arsenal that the country so badly needs.

EXPENDITURES OF ARTILLERY AMMUNITION IN RECENT WARS

Previous Wars Compared with One Month of World War

Year	War	Army	Rounds expended during war
1859	Italian	Austrian	15,326
1861-65	Civil	Union	5,000,000
1866	Austro-Prussian	Prussian	36,199
		Austrian	96,472
1870-71	Franco-Prussian	German	817,000
1904-05	Russo-Japanese	Russian	954,000
1912-13	Balkan	Bulgarian	700,000
1918	World War	Brit.& Fr.	12,710,000 one month[a]

Expenditures for One Year, Civil and World War

Year	War	Army	Rounds expended for one year
1864[b]	Civil	Union	1,950,000
1918[c]	World War	U. S.	8,100,000
1918[c]	World War	British	71,445,000
1918[c]	World War	French	81,070,000

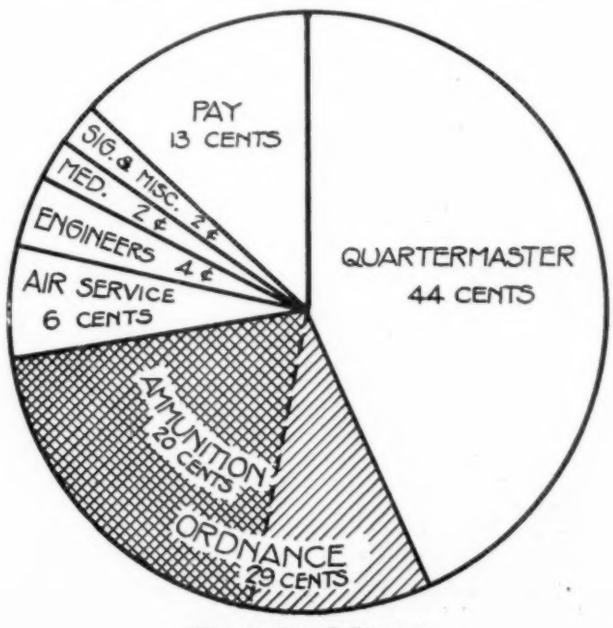
a. Average, year ended November 10, 1918. *b.* Year ended June 30, 1864.
c. Year ended November 10, 1918.

Schooling System: As already stated, the real basis of ammunition is chemistry. We cannot hope, therefore, to properly solve our problems until the workers on ammunition are well grounded in the basic principles and developments of chemistry. Up to the present, it is not believed that chemistry has been properly appreciated by the Ordnance Department or that sufficient training therein has been required of its officers, soldiers and employees.

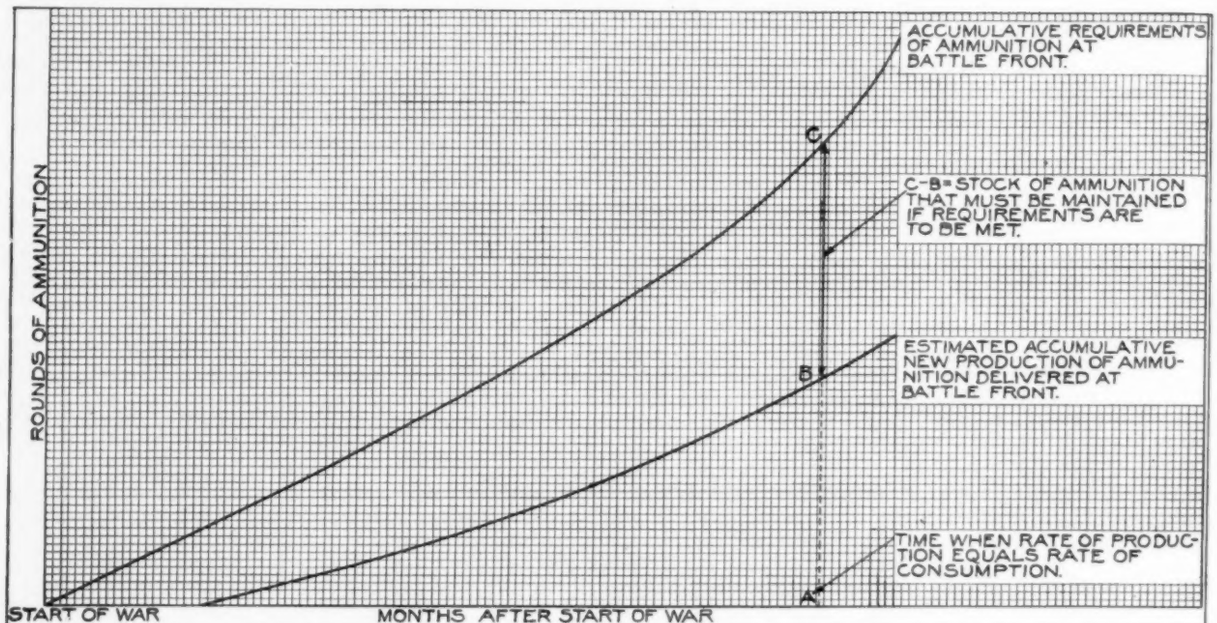
Under the present system Ordnance Officers are required to take a basic course at Massachusetts Institute of Technology. Chemistry is one of the subjects of the course, but it is hoped that the time and effort devoted to it can be materially increased.

Personnel assigned to ammunition work are also required to take a special course in the Ammunition School at Picatinny Arsenal, at which it is the intent to develop a well rounded out course covering the design, manufacture, storage and issue of ammunition and all of its components.

Ammunition Policy: If the industry of the country could be depended upon to produce, after the start of war, ammunition of satisfactory quality and in sufficient quantity to supply our war armies when mobilized and placed in action, the solution to our ammunition problem would be more simple, for it would then require that we have up-to-date designs of ammunition, a procuring plan for mobilizing the industrial effort of the nation, and only small stocks of ammunition to supply current needs of our peace army. But unfortunately, we cannot produce ammunition as rapidly as we can mobilize, train and place on the battle front our manpower. The experience of the World War proves quite conclusively that the delivery to the battle front of ammunition, produced in quantity after the start of war, lags behind new soldier manpower, similarly produced, by about one year. The solution, if we would have sound ammunition preparedness, requires therefore, in addition to design and procuring arrangements, that we maintain sufficient stocks of satisfactory munitions to supply our armies over the time necessary to satisfactorily develop new production. If we do not do



Where the Army Dollar went


ACCUMULATIVE REQUIREMENTS OF AMMUNITION AT BATTLE FRONT.
C-B=STOCK OF AMMUNITION THAT MUST BE MAINTAINED IF REQUIREMENTS ARE TO BE MET.
ESTIMATED ACCUMULATIVE NEW PRODUCTION OF AMMUNITION DELIVERED AT BATTLE FRONT.
TIME WHEN RATE OF PRODUCTION EQUALS RATE OF CONSUMPTION.
C
B
A
ROUNDS OF AMMUNITION
START OF WAR
MONTHS AFTER START OF WAR
THEORETICAL DEVELOPMENT OF STOCKS OF AMMUNITION THAT MUST BE MAINTAINED

so, it is inescapable that our Armies will have to fight the early months of a war without ammunition. England was faced with just this situation, in the early days of the World War. It should be remembered also that we fired very little artillery ammunition of our own manufacture during the entire war.

The theoretical statement of the stocks to be retained and maintained is illustrated in the accompanying diagram. Until the rate of production equals the rate of consumption, supply is not, of course, equalling demand. The difference between the accumulative-requirements curve and the accumulative-production curve at the time when production and consumption are in step represents the stock of that particular article that should be kept.

The matter of the requirements is, therefore, of paramount importance. It is dependent upon the manpower that we propose to place in battle, their armament, and the rate at which they are to consume ammunition. These are all matters of assumption, as no one can foretell who or where our next opponent in war will be nor how large or well equipped an army we will be required to utilize. A large requirement calls for tremendous stocks of ammunition and a small requirement has the opposite effect. Production can be reasonably well estimated by assuming that it will about equal World War Production.

It must also be remembered that these stocks have not lasting value for they are subject to chemical deterioration and to obsolescence. We all know that smokeless powder has a useful life of some 15 years only, and also that ammunition manufactured some fifteen or twenty years ago is so out-of-date from the standpoint of design and materials that it is of little use today. We must, therefore, admit that our stocks must be gradually replaced, at least, to the extent of about 1/15 per year, if we would keep them serviceable and reasonably up-to-date in design. Such replacements can only be made with money—and Congress has full control over its expenditure.

It is, therefore, apparent that only the highest military authorities are qualified to state the stocks of ammunition that should be kept. The establishment of these reserves seems to be the basic principle of a military policy, for they really measure the extent of our preparedness if we accept the principle that our military force is exerted through ammunition.

It is to be hoped, therefore, that the question—"What reserves of munitions and especially ammunition shall be retained and maintained"—will eventually be passed upon by the War Council and the Secretary of War as the policy making organization of the War Department and that their recommendations will be submitted to Congress for its support.

New Ballistic Tables

The Ordnance Department proposes to publish in the near future a set of ballistic tables which has been in course of construction the past three years. The amount of study which has been devoted to the subject of ballistics by the Ordnance Department during and since the War is perhaps not generally recognized. The use, during the war, of high velocity guns at angles of elevation up to 85 degrees made inadequate the old ballistic methods which were applicable only to elevation not exceeding about 20 degrees. This was especially so in the case of anti-aircraft guns where a knowledge was necessary not only of the range on the level of the ground but especially of the range to the point of burst. The ballistic tables when completed will fill a number of volumes aggregating about three thousand pages. They are based upon the latest information as to the law of air resistance and density of the air aloft.

It was found necessary during the War to have much more complete information than given by range tables for artillery that had been furnished in our service previous to the War. The modern range table must contain the answer to practically any question that can be asked concerning the artillery material to which it is applicable. Range tables in this form are being gradually prepared by the Ordnance Department for the service material. Where necessary, range firings are being conducted at the Aberdeen Proving Ground to obtain additional data. In all cases the tables are being prepared according to the latest ballistic methods.

Available Ammunition

By

R. L. MAXWELL
Member A. O. A.

A CONSIDERATION of the stocks of ammunition available for consumption by the using services at present calls for a hasty glance at the period immediately prior to the commencement of the World War. We find during that period very small amounts of ammunition of all classes; the stocks of seacoast ammunition unbalanced, that is, varying percentages of components of rounds on hand at Ordnance arsenals, Coast Defenses, and Seacoast forts; and only insignificant quantities of mobile artillery ammunition up to and including the 6-inch caliber.

The seacoast projectiles represented the accumulation of years of manufacture dating back in some instances to 1898. In general, the number of empty projectiles outnumbered the other components. The lots of projectiles differed somewhat in design and each Coast Defense had projectiles from a considerable number of lots. Such of the projectiles as were loaded had been loaded by enlisted labor under the supervision of line officers, as a rule unfamiliar with the problem of loading and assembling ammunition. Fuzes on hand had been manufactured at an Ordnance arsenal, tested, accepted and furnished to the Coast Artillery Service to be assembled into loaded projectiles when needed. Propelling charges in limited quantities were available in various stages of completion. As stated above, there was a general shortage of propelling charges compared with the number of projectiles available. The meager stocks of ammunition and scanty manufacturing appropriations kept target practice allowances very low, and firing of completely assembled service rounds by Coast Artillery troops was the exception rather than the rule, such firings as were possible being made with target practice projectiles.

In the Field Artillery the condition was somewhat different, but the amount of ammunition available for target practice during a training season was also very much limited. A battery's supply usually contained remnants of a great number of lots made at different times under different conditions with the result that it was usually impossible for a battery commander to segregate a sufficient number of rounds from a given lot to fire more than a single battery training problem with the same lot. Field Artillery officers as a rule, at the beginning of the war, had seen very little high explosive shell firing and troops had received no training in the use of the rather complicated fuzing system presented to them when the French matériel was adopted at the beginning of the World War.

The World War found the Ordnance Department, insofar as its ammunition manufacturing and testing activities were concerned, still in the component stage. There were no tests or opportunities for tests of completely loaded and assembled rounds of seacoast and mobile artillery ammunition manufactured or under manufacture at the beginning of the World War. Looking back at the early months of American participation in the war, it is apparent that there was very little appreciation at that time of the proportions that the ammunition activities of the Ordnance Department would assume during the course of the war. The first important development of the war from an Ordnance standpoint was the decision to equip the American Expeditionary Forces with French and British artillery, as this action placed the Ordnance Department in the position of starting from zero to build a reserve and start a river of supply of ammunition flowing toward the American Expeditionary Forces.

As the war progressed, stocks of ammunition of French and British manufacture, in some instances from American-made components, were purchased. Stocks of American manufacture following modified French and British designs accumulated from manufacture in the United States.

Still we found the Department confronted with the problem of keeping stocks balanced, that is, keeping the rates of production of components in step, and a study of the stocks on hand at the close of the World War shows that there had been an over-production of some components and that the Department and its production forces were at the close of the war just beginning to bring the ammunition problem out of the component stage. One of the most important lessons to be learned from the war ammunition activities is that all concerned in the production of ammunition must think in terms of *complete rounds*. The stocks of ammunition on hand today represented an investment of a considerable number of millions of dollars and while they constitute an important military asset, they also require, and will continue to require, the constant attention of the Ordnance Department to prevent their becoming a liability and to make it possible for the Department to fulfill its mission of furnishing the using services with serviceable ammunition for training purposes, and of being prepared to supply the United States Army with the necessary ammunition in the early stages of any future emergency.

Comparing a list of the stocks on hand today with a list of the stocks of April, 1917, we find many new items; for example, hand grenades, Stokes mortar ammunition, pyrotechnics, airplane bombs and chemical ammunition. Of these, chemical ammunition may be regarded as the one strictly new development in ammunition brought out by the World War. To take care of this new development, the Chemical Warfare Service was created during the war and has continued as a separate service of the War Department for the manufacture of gas and smoke-producing agents and the filling of these agents into shell, grenades and bombs.

A preliminary study of the stocks on hand at the time of the close of the World War showed that very little had been done toward improving pre-war conditions of stocks for seacoast artillery, and a general overhaul and rearrangement of seacoast stocks was undertaken in 1919. One of the outstanding features of the improvement made in seacoast stocks has become known as the "one-lot-per-battery" scheme of supplying propelling charges to Coast Defenses. As the name indicates, this scheme provides propellants all from the same lot for each battery. This is recognized as being a distinct improvement over the pre-war condition. All armor-piercing projectiles manufactured since 1917 are being loaded at an Ordnance establishment, and the question of inserting fuzes at the loading plant is under consideration in order to supply ammunition to Coast Defenses as nearly ready to fire as it is possible to have it.

Mobile artillery ammunition stocks in general exceeded the authorized requirements for reserve and current consumption during the stable life of the ammunition. A very thorough test of the quality of all mobile artillery ammunition and components thereof has been planned and is at present being executed at the Aberdeen Proving Ground. Upon the completion of this test, information will be available which, when added to the data previously obtained during the manufacturing records and acceptance tests of the lots made at the time of manufacture, will permit the classification of all mobile artillery ammunition into classes indicating its quality and suitability for service use.

A similar program is under preparation for checking by actual firings the quality of all stocks of seacoast ammunition and components with a view to similar classification of seacoast ammunition. It is probable that these check tests of the quality, stability and serviceability of ammunition will become a continuing function of the Ordnance Department in order to furnish information for use as a basis for salvaging surplus material so long as there are surplus stocks. Once stocks are reduced to the authorized reserves, similar tests will be required to furnish information as to the necessity for replacement of stocks by overhauling or new manufacture, in order to maintain the necessary and authorized reserves.

One of the factors which must receive a great deal of consideration in the solution of the ammunition problem at any given time is the fact that many items now in stock were manufactured during the war under war conditions of production by inexperienced personnel and organizations with new and untried facilities, following designs laid down to give ammunition for use within a very short period of time after manufacture. In other words, what was required and what was being made was something that would satisfactorily function within six months or a year after it was manufactured, not something that would keep fifteen or twenty years and then function satisfactorily. The factor of long storage has its influence on peace design and must be introduced into design of material manufactured in time of peace, but can be disregarded to a large extent during war production for war consumption. In certain instances there are items in stock which are already considered too dangerous for use in training activities, and for these items it will be necessary to furnish practice substitutes for use in training. The importance of working out and establishing a method of continually checking and following up the quality of ammunition stocks cannot be over-emphasized, and merits the best efforts and constant attention of the Ordnance Department.

Second only to the work incident to the checking of the quality of ammunition is the development phase and one which must always receive its due proportion of attention and effort. However, the idea is gradually taking shape that there can be such a thing as too much development and too little application of the results of development. The large automobile manufacturing concerns expend considerable effort toward turning out each year a model which is a marked improvement over the previous year's model, but as a rule it is just that—*an improvement, not* something entirely new. It is not believed that anyone can cite any instance of an automobile manufacturer turning out more than one model in a given year. An effort is being made to do somewhat the same thing in ammunition; that is, to bring out for the 1922 training season limited amounts of ammunition which can be fired by the using services at their schools and training centers, for the purpose of showing the using services what improvements are being made, and what the trend of development in ammunition is, and also to give the Ordnance Department an opportunity to test by actual firings conducted by the using services the correctness of their decisions relative to developments of ammunition.

Barring some unforeseen interference, it is expected that the Ordnance Department will be able to issue during the 1922 open training season a limited amount of 75 mm. ammunition embodying the latest improvements therein. For example, the latest proved design of projectile; for shell filler a grade of explosive which has not given any difficulties in firing or storage; a fuze representing the best effort of the Ordnance Department working in conjunction with the Field Artillery, which will eliminate the complicated system of fuzing left on our hands by the World War; and a flashless, smokeless, non-hygroscopic powder, the result of a number of years' effort on the part of the Ordnance Department and the DuPont Company to produce a powder which will be a step ahead of the powder used during the World War. If possible, similar ammunition for the 155 mm. Howitzer will be furnished, but probably in smaller quantities than for the 75 mm. Field Gun.

Similarly for the Coast Artillery, an effort will be made to furnish a limited number of a new type base-detonating fuze in case it is possible to conduct firing with service ammunition at any of the Coast Defenses or training centers of that arm. It seems reasonable to expect that the Air Service will be supplied with training bombs and the Infantry and Cavalry services with practice grenades as substitutes for high explosive bombs and grenades. All branches of the service may expect to have an opportunity of service-testing to a limited extent at their service schools and training centers several of the new types of pyrotechnics developed since the World War. If this season's efforts at getting into the hands of the using services the 1922 model ammunition are crowned with any degree of success, possibly we can repeat the performance in future years and give our Ammunition Arsenal and Ammunition Personnel something definite to work toward. With such a method of procedure in operation we would all be interested in the next season's model and would put the best that we have into bringing out something of which we could be proud. Aside from the advantage of having the year's work checked up by the using services through actual firings, we can also put into store a sufficient amount of the year's model ammunition manufactured to start the storage tests, pending results of which a final decision cannot be made.

At the close of the World War, at a final conference of the force of specialists who had been recruited and formed into an effective working organization at Picatinny Arsenal, it was resolved that, considering our standard World War high explosive as 100 per cent, every one present would do his part toward making it possible to fight the next war, whenever it comes, with a 300 per cent high explosive. It is believed that the same thought can be applied to all phases of ammunition, but instead of waiting for the next war to come to show our 300 per cent round of ammunition we should bring out each training season a round that will be judged a material improvement over the preceding season's output.

In conclusion, members of the Army Ordnance Association are urged to take advantage of every opportunity to witness firings of ammunition. There is nothing so helpful to anyone, no matter what his place in the scheme of organization, as to see the material, in the production and improvement of which he is involved, function and in use. The more ammunition we see fired, the further along in the game we can hope to get. Ordnance Officers, wherever on duty, can help the Department in fulfilling its mission of supplying ammunition and making ammunition available whenever and wherever needed by encouraging special exhibitions and firing demonstrations at any point within their jurisdiction. Line troops appreciate and respond to any efforts of the Ordnance Department to increase interest in ammunition and its ability to perform.

Artillery Fuzes

By

J. H. WOODBERRY

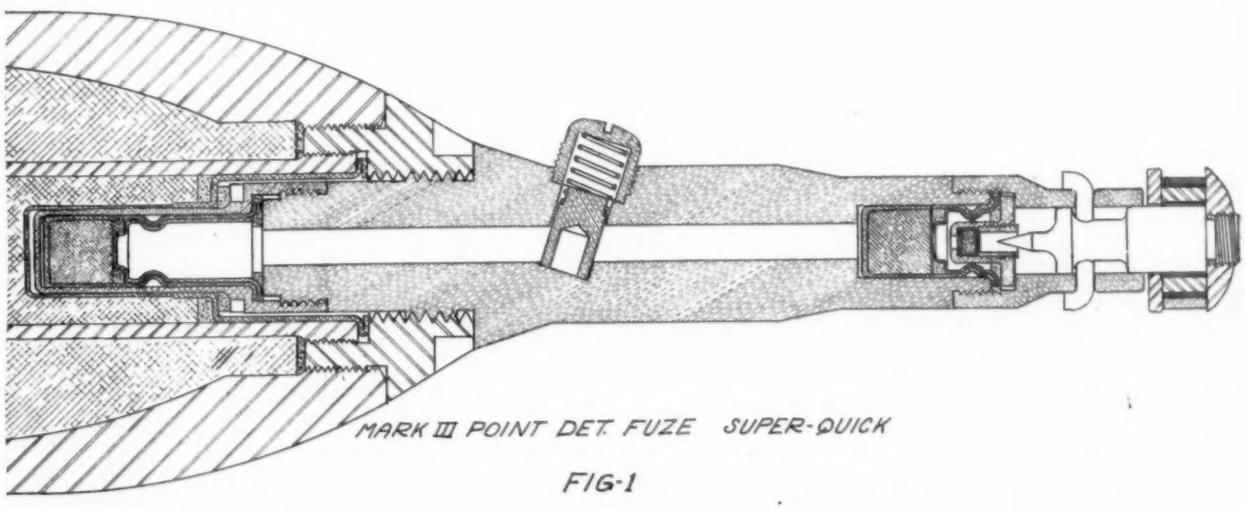
Member A. O. A.

IN ARTILLERY FIRE the usual mission is destruction of the enemy and his protection. Much depends upon the accurateness in placing projectiles at the desired point of destruction at the time required, and there is much dependence placed in the explosive charge and type of projectile used; yet with all the refinements of guns and gunnery, explosives and shells, in the final analysis, the effectiveness of artillery fire is measured directly by the final action of the fuze. Fuzes are, therefore, of the same relation to artillery as the balance wheel is to the highly specialized mechanism of a watch. Without an efficient system of fuzes, the splendid technical accomplishments in ranging apparatus, powerful and accurate guns and scientifically designed projectiles are all futile. Fuzes possess no spectacular interest and occupy but a small place in the make up of an army, yet there is perhaps no other unit of Artillery matériel which requires higher technical skill in its perfection or offers more difficulties in its design.

In the design of gun carriages, fire-control instruments, etc., there are certain known requirements to be fulfilled. These problems are solved by the scientific application of natural laws. Upon completion of one of these devices, trials are made, errors or weaknesses developed, and other sources of trouble become apparent in the performance. In fuze design, however, there are so many hidden requirements to be met, and such an abundance of potential errors lurking in every delicate piece, that laying down a successful design by pure laws of natural philosophy becomes practically impossible. Solution with this mass of uncertainty existing is still further obscured in its final stage by the necessity of destroying the article to be tested in testing its operation. In other words, instead of reaping satisfaction through the appearance of the article with all of its splendid perfection, it becomes necessary to blow it to atoms to see whether or not it works. If it works, well and good; if it fails, the evidence is gone. In testing, it must be attached to an explosive shell and fired away to prove its usefulness.

In fuze design it is rarely possible that the first models will prove satisfactory. Usually some degree of success will follow the initial attempt, thus adding a little impetus in development work, but ordinarily the process is a slow and painful one, fraught with many disappointments and defeats. The proposition of locating the defects is a matter of serious concern. Such questions as these are to be answered: Did it fail because the primer did not fire? Did it fail to arm? Did the delay pellet burn through? Or was it perhaps a failure of the booster or detonator? Maybe it was a faulty loaded shell, or perhaps the shell tumbled in flight, or the fuze unscrewed, or the impact was bad, or something gave way under the stress of fire. Was the premature due to a badly loaded shell or a porous shell base? The designer will swear by all the laws of nature and accompany his oath with all sorts of practical tests to show that the detonator was in a safe position when the gun blew up, yet something must have happened; the survivors of the gun crew will attest the accurateness of screwing the fuze home into the shell, of using the proper propellant, of the shell being properly protected with a base cover, and the like. Nevertheless the wreckage is appalling proof that something went wrong. What happened is seldom revealed by an examination of the débris. This is the usual preliminary reward of the most feasible designs.

But fuzes can be made which will function properly, they have been made, and they are still being made. So then, what is the secret solution of fuze design? You fire them



MARK III POINT DET. FUZE SUPER-QUICK

FIG-1

and they fail, or something goes wrong and your gun is blown to pieces. You examine the drawings, and all seems well.

But the solution of the problem, the reason for the mishap, yet remains to be discovered. When failures occur, or prematures shake the staunchest hopes, the thing to do is to go home and think it over. The fuze will usually divide itself into major problems such as mechanical functioning, workmanship, detonating ability, and the like. These points are separate studies. Other fuzes will be made exactly like those which fail. They will be fired inert for recovery and examination; they will be armed by spinning on the bench at gun speeds and will be dropped on plates to simulate the "set back" of the gun, they will be tested for safety and and in every other logical and illogical way which may possibly disclose the defect. By making these endless experiments some fault is usually detected which will explain the possible malfunction, yet in numerous cases, after all

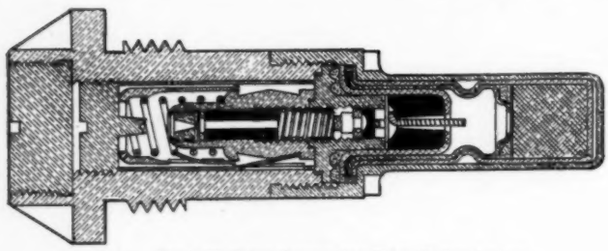


Fig. 2. Mark IV Point Detonating Fuze, Delay Action

have reached an agreement as to cause, it happens in subsequent test that the fault is still with us, or maybe it has been superseded by some other unexpected occurrence.

It may happen that after six months', or a year's hard work the design will be discarded through inability to correct its faults, but, nevertheless, the experience gained in this series of experiments lays the foundation for the next design, and now and then in the future turns out to be of unexpected value.

The development of fuzes does not rest with the successful test of experimentally made models. A satisfactory performance with the limited number is indeed an accomplishment, but the real test is a service test. The few fuzes made up for the initial try-out are usually made up by skilled workmen on precision machines; tolerances are held to the most favorable size and finishes of the highest order appear on all surfaces. They are hand made, as it were, and are nursed to maturity as pets. But when the sterner requirements of service are presented, the fuze must be made on a practical production basis. They must be manufactured on production machines and probably by inexperienced or at least uninterested help. Drawings, specifications and gauges tell the operator all that he wants to know about the job, and having complied with his interpretation of the drawing, etc., his responsibility rests. But to the fuze designer there is no rest in his mind until the first few lots have been manufactured and have satisfactorily passed the test. He then has his reward.

Drawings and specifications are, therefore, the fixed aim of the fuze engineer. These are indeed all that he will have left to show for his efforts when development has been completed. The fuzes have all been shot away and have gone up in smoke. In developing a fuze, therefore, the minutest details are mountains of importance to the engineer and require his concentrated attention. A draftsman has no place in an experimental shop, other than to transcribe the lines, figures, and notes indicated to him by detailed sketches.

It may be of interest to those who are mechanically inclined to illustrate a few of the principles utilized in fuze design, so a general description of the typical fuzing system will be given. A fuze may be defined as a device for exploding projectiles at a desired place. Detonating fuzes are used with high explosive shell, and time fuzes, which are not usually of the detonating type, are used principally with shrapnel. Detonating fuzes are classified as Point fuzes and Base fuzes depending upon their location in the shell. They are still further divided into types known as inertia-operated fuzes and supersensitive or quick-acting fuzes. In time fuzes there are two general classes; those operated by clock work, and those which depend upon a slow burning powder train for operation. The latter type is the more common.

The principle of operation of a detonating fuze is as follows: during the journey of the projectile, some attendant force, such as linear acceleration, rotation, angular acceleration, or air pressure is utilized, first to render the fuze safe while in the bore of the gun, and then to prepare the fuze for firing upon impact. When a fuze strikes a target offering sufficient resistance, a primer is fired either by the forward movement of a contained plunger or by compression on the nose of the fuze. The flame from the primer sets off the detonator, and the detonator being of fulminate of mercury, in turn initiates an explosion in an auxiliary charge of powerful yet safe explosive. This auxiliary charge is usually of tetryl and is called a booster. It in turn detonates the shell charge. In delay-action fuzes a slow-burning powder pellet is inserted between the primer and the detonator in order to slightly retard the transmission of flame to the detonator.

As an illustration of detonating fuzes; figures 1 and 2 are shown. Figure 1 is a quick-acting fuze, known as the Mark III Fuze. This fuze was extensively used in the World War by both the United States and France. A brief description of its operation is as follows: Upon firing, the two half collars between the head and the body of the fuze are held in place by a thin metal strip, wound about the half-collars in a direction counter to the rifling of the gun. Attached to the end of this spiral is another segment of a collar, which also acts as a support to the head as the projectile is forced forward into the riflings. Then, at an increasing speed, it assumes a combined rotational and longitudinal motion. The reaction to linear acceleration causes the head to bind tightly against the collars. At the same time the angular acceleration of the projectile causes the lug on the tap to resist rotation and lag behind, tending to wrap the tape tighter about the collars, thus resisting the effect of centrifugal force which tends to separate the collars and expand the tape. When the projectile emerges from the gun, linear acceleration dies away and changes direction, and immediately the collars under the influence of centrifugal force attempt to unwind the ribbon, by outward pressure. This is aided by centrifugal force on the lug and tape also, as angular acceleration likewise ceases as the projectile emerges from the gun, and the tape then unwinds under the action of centrifugal force and frees the collars. In the remainder of the flight, the firing pin is restrained from striking the primer by a shear wire. Upon impact, however, the pin is jammed into the primer, and the flash therefrom is immediately transmitted to the upper detonator, then through the channel to the lower detonator which detonates the booster charge and consequently the shell charge. While in flight the safety shutter is thrown open by centrifugal force, allowing free passage of the flame from the upper detonator to the lower one. The shutter is placed on an angle with respect to the axis of the fuze so that linear acceleration in the bore will prevent centrifugal force from opening it until it clears the gun.

Figure 2 shows the delay-action inertia fuze. This fuze was likewise used extensively during the war. The arming operation depends upon the reaction of the safety sleeves to acceleration. Upon firing the gun, the inner casing compresses the safety spring and unlocks the prongs of the outer casing from the lower flange of the plunger. The prongs on the inner casing engage the upper shoulder of the plunger and retain the safety spring in a compressed condition. As soon as the shell leaves the gun, linear acceleration changes direction owing to the cessation of powder pressure, and the pressure exerted rearwardly on the projectile by the air. Thereupon the plunger attempts to move forward but is restrained by the spring in the rear end of the plunger which is also attached to another part of the fuze. In this position the plunger rests until the projectile strikes a resistance. Then the plunger, under the influence of its own mass, continues its motion forward, and causes the primer to be stabbed by the firing pin. The flame from the primer ignites the delay pellet, and after burning through spits a flame through the delay pellet to the detonator. In non-delay fuzes, the delay pellet is omitted.

Another interesting fuze is that designed for use in small projectiles from one airplane against another: Figure 3 shows such a fuze. Its novelty resides in the utilization of air force to render it safe in flight. Upon firing, the pin and its holder rest on two half discs which are normally held together by a spring wire wrapped about them. Linear acceleration causes these two blocks to hug the bottom of their seat, resisting centrifugal force until the projectile is out of the bore. Thereupon they fly outward and leave no material barrier between the firing pin and the primer. The air pressure on the nose of the fuze in flight is enormous, and the most natural thing for it to do is to move rearward against the primer. Such is not the case, however, as will be seen later. It is true that the air pressure is sufficient to drive the pin rearward, were it not opposed, but, fortunately, the designer takes into account the difference between dynamic and static force, and therein lies the safety of the fuze. The air flowing against the head of the fuze exerts a pressure dependent upon the shape of the nose for its effectiveness. The rounded corners, therefore, lessen the effective pressure. Now, through the perforations in the centre of the nose, air enters the cavity under the cap, and at a pressure equal to that against any other part of the nose. But this pressure is static. The air therein has practicaly no movement, a characteristic of its static pressure being that its force is exerted equally in all directions, and hence the total force opposing this dynamic force of air is that of the static pressure over an area equal to the cross section of the head. The total force being independent of the interior shape gives a greater restraining force naturally, than the rearward force externally, and the firing pin flows in the air in a forward position. Upon impact with the target, such as the wing of an airplane, the flow of air into the cavity is shut off and by reason of the vents on the side of the cup, the pressure is immediately released entirely. The inertia of airplane linen is then sufficient to drive the firing pin into the extremely sensitive primer and cause the shell to explode.

Since the conclusion of the war great strides have been made in fuzes, particularly in the safety and detonating qualities. It is contemplated that the present types of fuzes

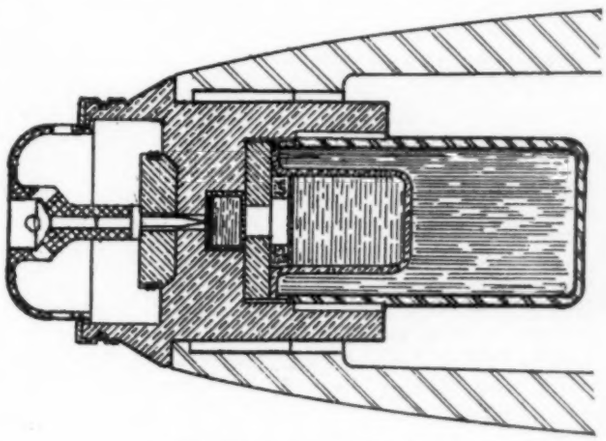


Fig. 3. 37 MM. Fuze, Supersensitive

will eventually be replaced by those of a safer type for firing, and one which will be more efficient in completely detonating the shell charge; but until these designs have been adopted a description of the fuzes will be withheld for obvious reasons. It may be interesting to note, however, that in these new designs the detonators are in a position remote to the booster, and should a detonator fire prematurely in a gun or while handling, no damage will result to the fuze, other than the destruction of the detonator. Another new feature of these fuzes is their ability to detonate a shell with a large air gap existing between the booster and the shell charge. Such conditions often exist in the service when the shell charge compresses under the forces of setback and leaves the booster suspended in air. In existing fuzes, such an air gap is fatal to detonation; but with the new fuzes it has been found that a gap of six inches in shell loaded with picric acid, amatol, or TNT does not affect the quality of detonation to any noticeable degree. A further improvement is made, in that it is possible, with a simple change in the position of the nose of the fuze to be made at the gun if desired, to have the fuze give superquick action or delay action at will. This will simplify the fuzing problem of shells, and reduce the transportation of several types of fuzes in time of war.

Test of Short-Base Range-Finders

The results obtained from the recent test of short-base range-finders emphasize the need of further research work upon these instruments. Accordingly an extensive program for the study of range-finders at Frankford Arsenal has been inaugurated and special testing instruments are now being built at the Frankford Arsenal for this purpose.

However the result of most immediate application shown by the test is the striking difference in the ability of different range-finder observers and the splendid improvement which can be obtained by special training of the personnel. Seventeen observers were employed, all of whom were enlisted men. Ten of the men were given a week's special training in using the range-finder before the test was begun and the poorest of the ten was better than the best of the seven without the special training. This result is the more remarkable when it is added that the ten men who had the special training were new recruits in the army, and had had no previous experience with range-finders, whereas the other seven had considerable experience in the use of range-finders during their service in the army, and several of them were non-commissioned officers. The difference between the ability of the various observers was much wider than that between the best and poorest instrument. In fact, this difference was so great that the poorest observer would require a 2-meter base instrument in order to equal the performance of the best with a 1-meter base range-finder.

Projectile Design

By

R. H. KENT

Member A. O. A.

DURING the World War, the Ordnance Department expended approximately four billion dollars. Of this sum approximately two-thirds was expended for artillery ammunition. In view of the vastness of these sums it would seem to be a matter of considerable importance that this ammunition should be of the best possible design. A large proportion of this ammunition would have been used for barrage work or against definite objectives in which case the value of the ammunition would probably be approximately proportional to its accuracy. It is therefore a fair statement to say that an improvement in the design of these projectiles which would have halved their dispersion would have increased the value of this ammunition by an amount which would be measured in the hundreds of millions of dollars. Again, with the more accurate ammunition, the same military effect could have been produced with a much smaller number of rounds, resulting in the saving of hundreds of millions of dollars.

In view of the great importance from an industrial and military point of view of increasing the accuracy as well as the range of projectiles, it might have been expected that extensive experiments would have been undertaken by the various armies of the world with a view to the production of projectiles of improved shape and balance, and that a steady improvement of design in these respects might have resulted. Such an expectation, however, would not be justified by the facts. The shape of the projectiles used by all the belligerents at the beginning of the World War was to all intents the same as the shape of the projectiles manufactured in the early eighteen-sixties when the use of rifled cannon first became general.

The first signs of an awakening from the general lethargy from which projectile design had been suffering for a period of over fifty years were the introduction of long pointed caps for armor-piercing projectiles in the United States in the year 1911 and an extensive series of experiments by General Desaleux in France about the same time. The effect of these latter experiments began to make itself felt soon after the beginning of the World War, and during its progress noteworthy advances in design were made by the French and the Germans, the British lagging somewhat behind. The shell manufactured in such large number in the United States were for the most part duplicates of the French and British designs which were current at the time the United States entered the war. This was by virtue of the policy which was adopted of making our ammunition interchangeable with that of our allies.

In attempting to discover the reasons for the backward state of projectile design which prevailed for so long a period, the laymen is perhaps tempted to place the responsibility upon official inertia and conservatism and lack of a high grade of engineering intelligence. To do so, however, would not be entirely fair for during this period when projectile design was at a standstill, engineering talent of a high order was displayed in the progress made in the design of other material. The intricate mechanism of a disappearing carriage for a seacoast gun and the perfection of design shown in the French "75" may be cited as examples. The explanation seems to be in the fact that the fundamental engineering science and theory for the design of guns and carriages was already at hand in the science of mechanics and the science of elasticity and the strength of materials, while there was at hand during this period no satisfactory theory of the motion of projectiles. Such theories as were advanced by General Mayevski of the Russian Artillery in 1872 and others, were of an extremely complicated and recondite nature and were not given any experimental demonstration whatsoever. Under such circumstances skepticism as to the value of their results was to be expected and they had no influence on projectile design. As a matter of fact, their theories, while in general mathematically correct, were based on various contrary-to-the-fact assumptions which quite vitiated the conclusions attained.

More recently, considerable work has been done in this field by Charbonnier, Cranz, Prescott, and Esclangon, but assumptions of a restricted nature were introduced and the theoretical results were given little experimental trial. During the latter months of the war a thorough theoretical and experimental analysis of the motion of projectiles was undertaken at the British Anti-Aircraft Experimental Station at Portsmouth. The results of this investigation are now available in a paper in the Philosophical Transactions of the Royal Society by Messrs. Fowler, Gallop, Lock and Richmond entitled "The Aerodynamics of a Spinning Shell." The theories advanced in this have in general been confirmed by the firings made at Portsmouth and have been given in some respects a much more satisfactory demonstration in the firings made at Aberdeen Proving Ground.

It may, therefore, be stated that the theory of the motion of the projectile is now in quite as satisfactory a condition as the theory of the strength of materials and that it would now be quite as senseless to fail to consult it in the design of projectiles as it would be to fail to make use of the theory of the strength of materials in the design of a gun or a carriage. It is true that the "Aerodynamics of a Spinning Shell" involve a theory which is rather complicated in view of the complex reactions of shape, spin, and balance upon range and deflection. It is, however, not nearly so complicated as a good deal of the electro-magnetic theory which is daily used in the design of telephone circuits and electric power systems.

In order that a complete system of exterior ballistics may be of practical value in projectile design, it is necessary that a body of engineering aerodynamic data be obtained for different projectile shapes quite as much as it is necessary to have data regarding elastic limits and tensile strengths if one is to use the theory of the strength of materials in designing a gun.

The sort of information needed is the answers to the following questions: Given a projectile of a certain shape and moving at a definite velocity; (1) What is its resistance when moving head-on? (2) If its axis makes a given angle (called angle of yaw) with its direction of motion, what will be the increase in its head-on resistance, and what will be the amount of the lateral push tending to displace the projectile to the side? (3) If it makes a given angle of yaw, how great will be the moment of the air pressure about its center of gravity tending to cause it to tumble, which must

be resisted by its energy of rotation? (4) If its axis is turning pivoted at the center of gravity, what is the resistance to such a turning motion?

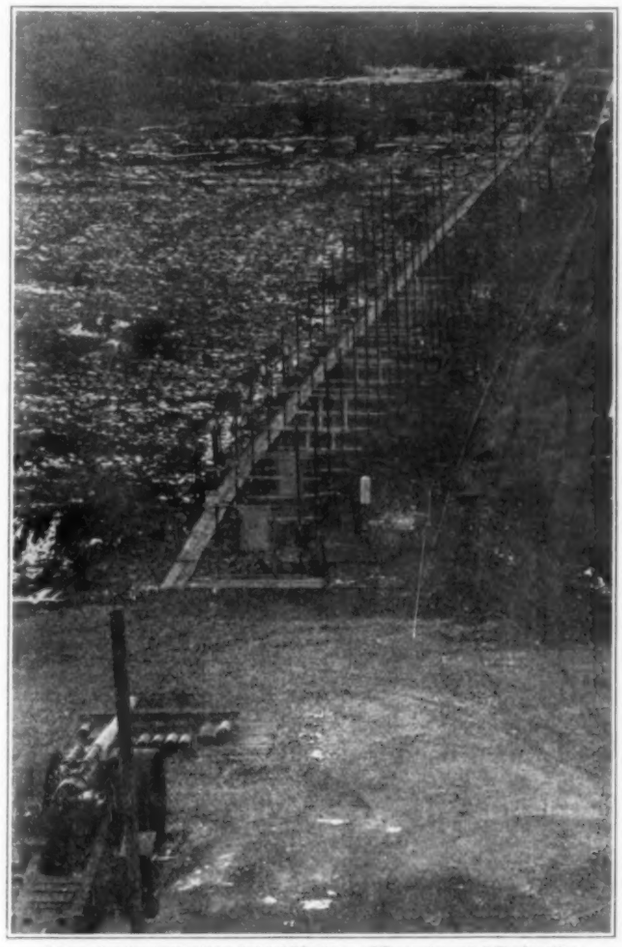
The answers to these questions provide the data for calculating the effect of the wobbling of the projectile near the gun on the range and deflection. Another set of questions of equal importance are the following: (1) What is the effect on the resistance of a projectile of making a slight change in the angle of boat-tail? (2) Of changing the length of flat between the band and the corner of the boat-tail? (3) Of making a slight change in the height of ogive? The answers to these questions provide the basis for making a rational system of tolerances on projectile dimensions. A lack of such information was a notable handicap to the Ordnance Department during the war.

In order to obtain data of the kind mentioned above, a range for 3.3-inch experimental guns has been established at Aberdeen Proving Ground. The general characteristics of it, with its jump cards for the study of the initial motions of the projectile and its precision chronograph coils for the making of accurate resistance measurements, are shown in the accompanying photograph. The idea of the range was suggested by the British range at Portsmouth. That it is a going concern is largely due to the active support and co-operation which the Ammunition Division has received from the Technical Staff. The firings are at present being made by Mr. C. D. Knight under the direction of Capt. M. M. Serum. The lengthy and laborious work of the reduction of the observations has, for the most part, been done by Mr. C. P. Hitchcock, while much careful work in measuring moments of inertia and of the dimensions of the holes in jump cards has been done by Mr. P. R. Bond.

The precision chronograph which is now being used in these firings has been developed by Dr. E. C. Eckhardt of the Bureau of Standards with the co-operation of Major Hull, then of the Technical Staff, in the earlier stages of the work. Mr. A. D. Millar, of the Proving Ground, has given valuable assistance in the work of testing it. By its use, it is possible to measure a velocity with as great precision using a screen interval of ten feet as is obtained with the Boulenge-chronograph using a two hundred foot screen interval, and there is no difficulty experienced from the failure of the Boulenge-screen wires to break, which makes such an instrument quite unsuitable for use in experiments of this sort.

When the proper aerodynamic data for a certain shape of projectile have been obtained from the analysis of the behavior of a small number of experimental 3.3-inch projectiles, the results are immediately applicable to the design of any similarly shaped projectile, no matter what its size, distribution of weight, or twist of rifling of the gun in which it is to be fired. From this point of view these experimental firings of 3.3-inch projectiles may be regarded as model experiments in projectile design, having a similar function to the experimental tanks in which model ships are tested. By the proper use of model experiments of this sort it is believed that it will be possible to make continuous advances in projectile design at a cost which is a very small fraction of what it would take by the old empirical methods.

To illustrate how unsatisfactory it is to attempt to use actual range firings as a basis for the improvement of projectile design, consider that a projectile has been fired and that its range dispersion has been found to be large. The question arises as to the cause of the dispersion and what must be done to correct it. Suppose that the powder tests have shown that muzzle velocity is uniform and recovery tests indicate that no fringing and no slipping of the bands has occurred. The dispersion may then be attributed to any one of the following causes: (1) variation in atmospheric conditions, (2) variations in the shape from round to round, (3) improper action of the projectile in the gun and at the muzzle, (4) improper balance and ratio of moments of inertia, (5) insufficient or too much spin resulting in either great wobbling near the gun or large yaws near the vertex, (6) incorrect shape such that the wabbling near the gun is not quickly damped out. Any one or any combination of these causes may be responsible for the large dispersion observed. It is obviously impossible to infer from the fall of the shots which of these various causes is preponderant. It seems evident that in so complicated a question the only hope of reaching a solution of the difficulty



Range for Investigating Initial Motions of Experimental Projectiles

aside from numerous and costly trials of various combinations of different shapes, weights, spins and balances is to make a thorough analysis of every factor of the problem. In fact, to design a projectile without having previously obtained the appropriate aerodynamic data and having calculated the effects of the air forces on the behavior of the projectile is equivalent to designing a gun without any knowledge of the properties of the materials used in its construction and without having made any calculations as to the ability of the materials to endure the stresses to which they will be subjected.

In the absence of any application of theory, progress has been made and can, of course, continue to be made. Without a very liberal expenditure of funds such progress will be slow and it will be difficult under such circumstances to resist that spirit of conservatism which was able, for a period of over half a century, to prevent any improvement in the shapes of projectiles. It is such considerations as these that have dictated the policy of the Ammunition Division in regard to projectile design.

Artillery Shell Production

By

DALE C. HALL

Member A. O. A.

THE design and manufacture of artillery shell cannot very well be considered separately because in every case the final test which determines whether a design is satisfactory is whether it can be manufactured in quantity under conditions which obtain in war times. This test is one which is very often forgotten during a long period of peace when the funds available for ordnance work are very limited and only small quantities of shell can be made, in most cases hardly sufficient to establish the necessary machining and inspection processes.

It is not the purpose of this article to discuss at length the design and manufacture of shell, for this is in general familiar to most people, through the articles that were written and published during the war and through personal contact with people who worked on the manufacture of shell, but it is desired to take up certain features of design and manufacture which caused great trouble during the war and discuss the steps that are being taken to guard against similar difficulties.

When this country entered the war in April, 1917, very few people recognized the magnitude of the ordnance problem and especially that part of the problem which covered the manufacture of shell, banded and ready for loading. Only a very few officers were familiar with the manufacture of shell and even these officers were handicapped by the lack of information on the requirements for quantity production of ammunition under war conditions. Prior to this time practically all the shell had been machined at Frankford Arsenal or Bethlehem Steel Co., or at some other plant which had equipment especially designed for the work and very little difficulty was encountered in producing the relatively small number required. Some study had been made of the production problems encountered by commercial manufacturers who were working on British, French, and Russian contracts, but the designs and the methods of manufacture were different from American designs and methods of manufacture and it was thought that our designs were satisfactory and could be produced in quantity. As a matter of fact, this assumption was true to a certain extent, for the Ordnance Department did not have any very great difficulties in producing 3-inch common steel shell and shrapnel in large quantities, and several millions had been manufactured before the contracts were amended to cover the manufacture of 75 mm. shell and shrapnel.

The adoption of French types of shell (75 mm. and 155 mm.), however, placed the Ordnance Department in such a position that it could not use to full advantage the knowledge which it had gained of the design and manufacture of American shell, and furthermore, it placed the arsenals on almost the same basis as a commercial plant, for they had to rearrange their equipment and train personnel to manufacture practically new designs. The French rendered what assistance they could but their methods of manufacture were not suited to American practice. Attention is called to the fact that our arsenals produced only a very small number of shell during war times, partly because of the difficulties mentioned above and partly because a large part of their facilities and personnel were engaged in experimental work.

The work of the Ordnance Department was greatly increased not only from the standpoint of changing to new methods of manufacture, but also from the standpoint of the quantity that had to be manufactured. This latter consideration had a very far-reaching effect because it at once became necessary for the Government to control the supplies of raw material and the Ordnance Department, already handicapped by the production of designs with which it was not familiar, had also to prepare specifications very different from those used heretofore. The preparation of these specifications for steel, forgings and machined shell was one of the most difficult problems the Ordnance Department had to solve.

The specifications used by the Ordnance Department until June, 1917, were those contained in Ordnance Office Pamphlet No. 452-B called "Instructions to Bidders and Specifications Governing the Manufacture and Inspection of Common Steel Shell and Shrapnel." This was a specification dealing only with finished shell and shrapnel which were accepted if they passed the prescribed firing test. No particular attention was paid to the chemical or physical properties of the steel or forgings as this was a matter for the contractor to look out for as his product had to meet the firing test. The first specifications under the new plan; that is, separate specifications for the steel, the forging, and the machined shell, were issued in June, 1917, but did not stand very long on account of the constantly changing requirements, for in addition to the French designs which had been adopted, British designs (8-inch and 9.2-inch How.) were also adopted. The French and British specifications were radically different from each other as well as different from our own specifications, and the situation was still further complicated by the widely divergent views of the steel, forging and shell contractors. There is no doubt that they were sincere in their recommendations but they were based primarily upon their own experience and represented for the most part practice applicable only to their own plants. In December, 1917, however, most of the difficulties, particularly with respect to the chemical composition, physical requirements, heat treatment, etc., had been ironed out and the specifications adopted in that month were used with but minor changes throughout the war.

Since the close of the war a careful study has been made of the specifications for steel, forging and shell, and there are now being prepared in the Ordnance Office a new set of specifications which are based upon the results obtained during the war. These will be practical war-time specifications for quantity production and will prescribe as wide limits as possible consistent with the requirements that must be met. It is probable that the firing test for finished shell will again be inserted in the specifications, for the Ordnance Department is not hampered, as it was during the last war, by the lack of adequate proving-ground facilities. These new specifications will be used at all government arsenals and in placing orders with commercial contractors, and every effort will be made to insure that they are practical from both a manufacturing and inspection standpoint.

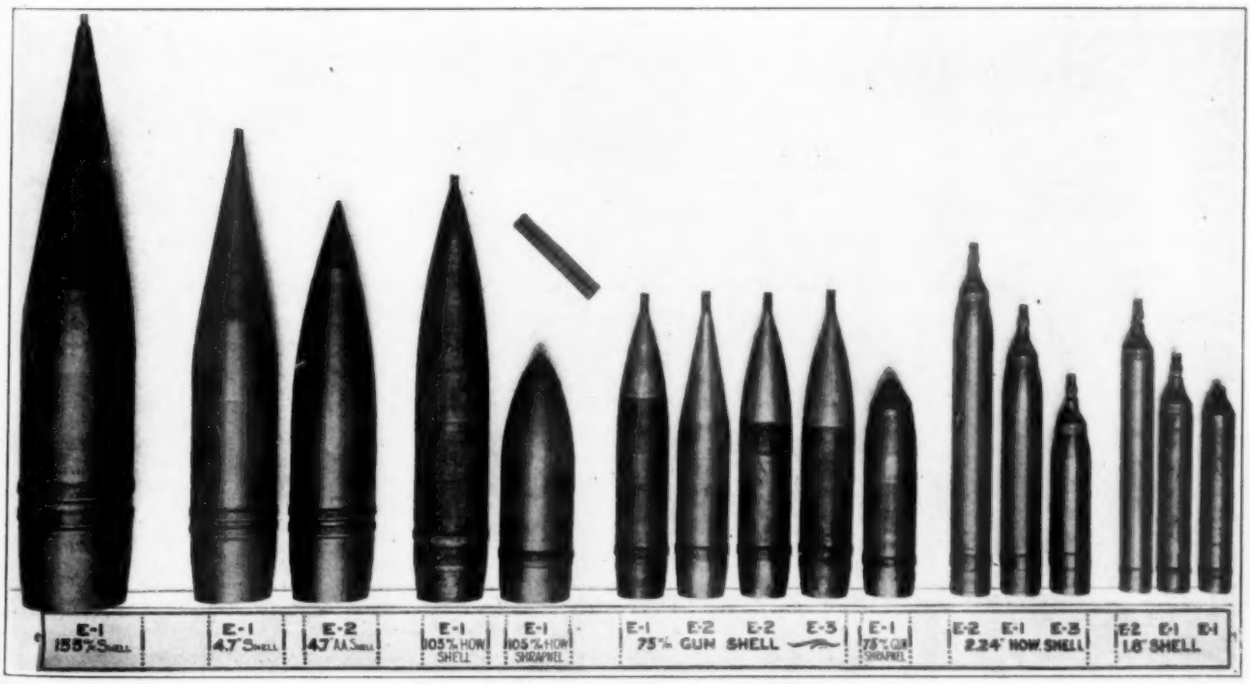
Another problem which caused a great deal of trouble during the war and which has a most important bearing on the design and manufacture of shell is the question of tolerances on the various dimensions. If a French, a British and an American shell drawing for approximately the same caliber of shell are laid on a drawing table and the tolerances on the same dimensions on the three shells are checked one against the other, one realizes at once what a difficult problem the assigning of various tolerances must be. All of the shell, the British, French, and American, perform as intended during firing test yet they are radically different at various points. The natural question of course and the one most frequently asked by contractors during the war was, "The British allow so much on this dimension while you allow only one-half as much, why cannot that tolerance be increased?"

There is no satisfactory answer to such a question because each tolerance specified presumably represents the results of experience and is correct for that particular design. The fact that the British or French are able to allow greater tolerances than we do is probably because that particular design taken as a whole permits of wide variations on some dimensions with little or no effect on the flight. In our own tests it has been found that if a band is placed well upon the shell a rather wide tolerance can be allowed without any bad results, while if the band is placed very close to the base of the shell, the slightest variation in the location of the band has a very marked effect. Perhaps it may be possible to base the tolerances on some rule such as the following: The more perfect the design, the greater the tolerances that can be allowed, the idea being that if the location of the band and the shape of the ogive are the best for that design, then comparatively large variations from them will have very little effect.

At the close of the war the Ordnance Department manufactured a large number of 155 mm. shell which were as near the mean dimensions on the drawing as it was possible to make them except for that particular dimension or tolerance on dimension which it was desired to test. These projectiles were fired for comparison with standard shell and while the results were not conclusive and applicable to 3-inch or 16-inch projectiles, they did show that for the 155 mm. shell there were various dimensions which could have varied much wider than allowed on the drawing without any bad effect on the ballistics. There are, however, various dimensions which should have had smaller tolerances, and an incident that occurred during the war illustrates this very well. During the forging of the 8-inch common steel shell it was found that scale would fall into the die pot at certain points with the result that the forgings had black spots on the base which would not machine out. Without any very definite information on the subject, the Ordnance Department allowed the manufacturer to bevel off the base so that the shell would clean up. No effort was made to make the angle at the base uniform, and in fact the matter was not further considered until some surprisingly disappointing results were obtained during the firing test which were directly traceable to this angle machined at the base of the shell. This incident is cited to show not only the variation which this slight change made but also the lack of information on shell design and tolerances.

In addition to the firings with 155 mm. shell mentioned above which, by the way, were rather costly, the Ordnance Department is perfecting a solenoid chronograph which will enable one to accurately determine the resistance of a projectile, and it is believed that this will be a satisfactory and comparatively inexpensive method of accurately establishing just and liberal tolerances which will facilitate manufacture and at the same time secure the desired result at the target. The wind tunnel experiments conducted by Major G. F. Hull, at Lynn, Mass., have also contributed some valuable information on this subject particularly with reference to the band resistance and location of the band. The whole subject, however, is a very difficult one to handle and will require a large amount of experimental work to obtain a satisfactory solution.

While the correction of tolerances and the preparation of satisfactory specifications will be a great advance in projectile design and manufacture, the greatest improvements are those which made easier the manufacture of the shell.



Experimental types of projectiles of various calibers

In the accompanying illustration there are shown some of the various types of projectiles for the Westervelt Board Guns. All are still in the experimental stage and preliminary firings have indicated some desirable changes. In the small calibers such as 1.8-inch and 2.24-inch Infantry Howitzer Projectiles and 155 mm. Trench Mortar Shell, the use of seamless steel tubing with a welded in base has been tried and the results obtained on firing test have been satisfactory. It is believed that this type of construction may be well adapted for the 75 mm. shell and that the use of extra heavy pipe may be permitted in place of steel tubing. The projectiles have behaved well on ballistic test and even though very few firings have been made, a marked improvement in range and accuracy has been noted. Another change in design that has been made which has great possibilities is the use of straight wall steel without any nosing in. This design is much easier to manufacture, behaves very well during flight, and will also permit of carton loading. This latter consideration is one of great importance and is being given considerable attention. It would certainly solve the problem of storing shell for an indefinite period as well as make the loading operations more flexible.

The large caliber shell are provided with false ogives and are much longer than any previousy used. The ogives are a new problem in shell construction and various types have been made from aluminum, malleable iron, steel forgings and sheet steel rolled and welded, the last named one being a method used by the Germans.

There are many other phases of this subject which might be discussed but the question of satisfactory tolerances and satisfactory designs which can be produced in quantity under war conditions are the most important. The results obtained to date have been most satisfactory from an ordnance standpoint and it is believed more real progress in the design and manufacture of shell has been made in five years than the fifty years before the war.

Ammunition Loading and Assembling

By

FRED HAWKES
Member A. O. A.

THE problems met with in the development of methods and the practice of loading and assembling ammunition vary considerably in difficulty according to the purpose for which the ammunition is meant. Armor-piercing projectiles form perhaps the most difficult type of ammunition to load and assemble so that the desired functioning may be obtained.

A complete, loaded projectile, ready to fire, consists of a loaded fuze, booster and shell. The fuze is usually made to function either on impact or after a certain time has elapsed. It contains a charge of fulminate of mercury or some other extremely sensitive explosive which detonates under the action of friction caused by a firing pin. This initial detonation is transmitted directly to the bursting charge of the booster in the case of instantaneous fuzes, or in the case of time fuzes is held up for a definite period of time by means of a black powder delay element before the final detonation is transmitted to the booster charge. The booster charge consists usually of pure TNT or tetryl compressed within a metal container, and its intensive detonation causes the detonation of the main charge of the projectile. It must be understood that in the case of instantaneous fuzes this series of detonations is practically instantaneous.

In the case of artillery ammunition special precautions have to be taken to obviate the evil effect of "set-back," the name given to the tendency of the charge in a projectile on propulsion from the gun to move in the direction opposite to the line of flight of the projectile, this effect being the same as occurs in the case of a street car suddenly starting forward, where a person in the street car tends to fall away from the direction of movement. This set-back may have serious consequences in the case of ammunition loaded in a faulty manner, and special precautions must be taken, especially in the case of ammunition loaded for high powered guns. The sensitive fulminate charges in the fuze must be pressed to a sufficient density to prevent the consolidating effect of set-back, because movement develops heat, and heat can cause the detonation of a sensitive explosive. The booster charge also must be compactly pressed, as even where premature explosion from movement of the charge due to set-back does not occur, a gap is formed between the detonator of the fuze and the booster charge, which militates seriously against the efficiency of transmission of detonation from the fuze to the less sensitive booster charge. Air gaps in a detonating system form one of the chief causes of faulty detonation or failure.

The main charge in the case of point-fuzed shell is usually of TNT loaded by melting the explosive and pouring it into the shell, a cavity for the booster being drilled in the charge after solidification has taken place. TNT shrinks on changing from liquid to solid, liquid TNT also contains occluded air and other gases which separate out when the liquid TNT changes to the solid state. The top part of the TNT charge in contact with the cooler atmosphere solidifies first, and the combined effect of shrinkage and separation of dissolved gases is to produce cavities in the head of the charge underneath the previously solidified top layer, this phenomenon being known as "cavitation." A shell loaded with high explosive containing cavities is highly unsatisfactory if not dangerous, as the sudden collapse of the charge on firing from the gun may produce premature explosion, or if a premature does not occur the cavity produced between booster and main charge may cause faulty transmission of detonation.

TNT as used in shell loading is not pure trinitrotoluene but contains lower nitrated toluenes and isomeric forms of trinitrotoluene which exist as oily impurities. Unfortunately these oily impurities slowly segregate from the charge after solidification has taken place and are forced

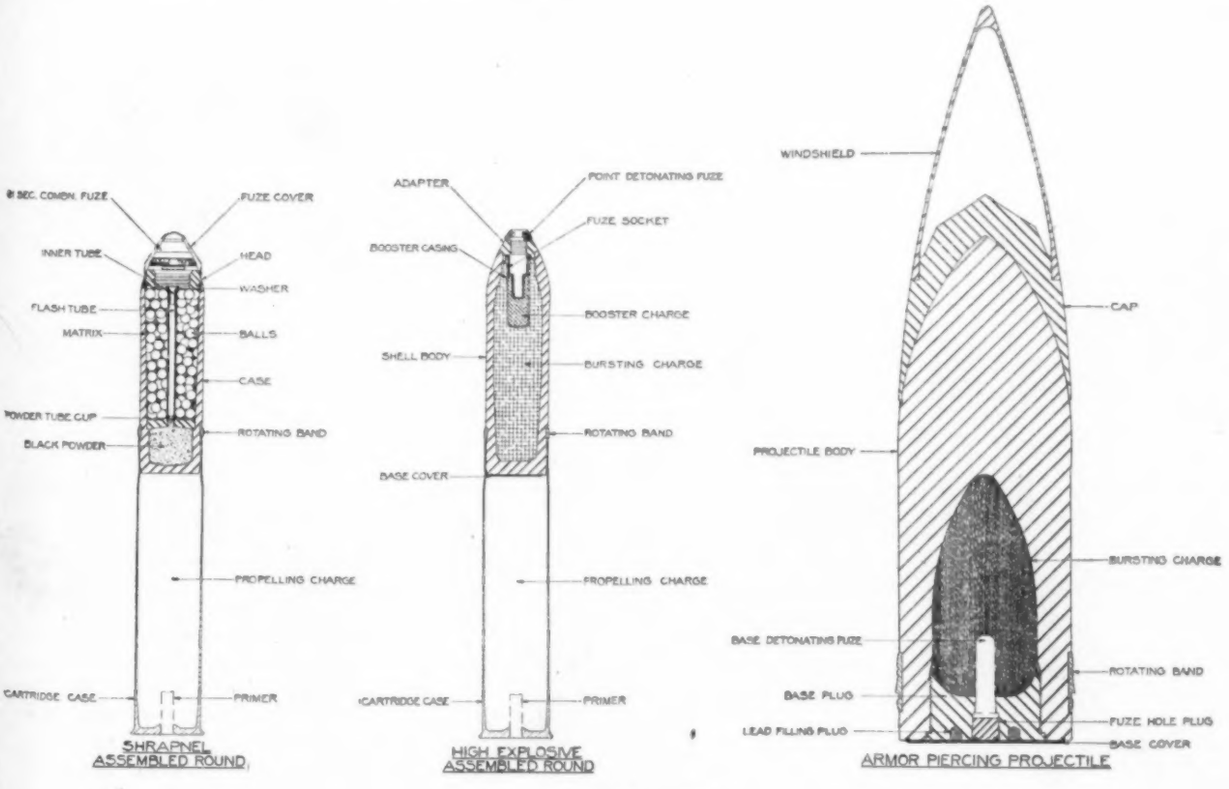
in the case of point-fuzed shell towards the screw-threads in the nose, producing what is known as "exudation." The presence of exudation products is very undesirable for two reasons. These oils are less sensitive than TNT and produce insensitiveness in the booster charge where they usually find their way after they have passed through the screw threads, this insensitiveness resulting in no detonation of the shell charge, or only partial detonation. It is also found that the exudation products carry with them small quantities of solid TNT which are deposited in the screw threads giving danger of premature when the shell is fired from the gun owing to this finely divided TNT being nipped between the screw-threads under the sudden shock of discharge. It has been found that ordinary glue forms an effective seal against the passage of these oils, and hence all screw threads in TNT loaded shell are carefully treated with glue before assembly takes place. In consequence of the frequent non-observance of this precaution in shell-loading during the war, it is a familiar sight in shell storage depots to see this oily substance in small pools on the ground under the racks containing shell lying horizontally, or to see it smeared down the sides of shell which stand upright on the ground. Exudation is most extreme with impure forms of TNT in hot climates, and hence for shell which it is known are to be stored in tropical climates the purest available grade of TNT is used.

The difficulties met with in the loading of ammunition for high-powered guns do not apply to such a great extent to Trench Warfare Ammunition. In trench warfare, mortars of low power are used, or the missles are thrown by hand. Special care, however, is taken in the case of the larger calibered mortars to prevent prematures occurring. In the case of hand grenades care is taken that the charge is sufficiently consolidated to prevent movement of the charge during transportation and use.

With airerfaft ammunition, the propellant is gravity and acceleration is not applied suddenly as in the firing of a shell from a gun. Hence the loading of this type of ammunition is not so great a problem as in the case of artillery ammunition.

As previously stated, the loading of armor-piercing projectiles offers most difficulty, because in addition to withstanding the shock of set-back on discharge from the gun, this type of ammunition has to withstand the shock of "set-forward" on impact against armor plate. This latter shock tends to move the charge of fuze, booster or projectile forward in much the same way as a person is jerked forward in a street car when the motorman puts on the brakes. The tremendous effect of impact of a 12-inch projectile against a 12-inch armor plate should be seen to be appreciated. For one of these projectiles to function correctly it must pass through the armor plate intact and burst, in the case of a delay fuze, at a reasonable distance behind the plate. TNT is not used in the loading of armor-piercing projectiles as it is too sensitive to withstand this shock of set-forward. Explosive D or some similar less sensitive explosive is used, and movement of the charge on impact is guarded against by the use of a charge of high density and one of even density throughout.

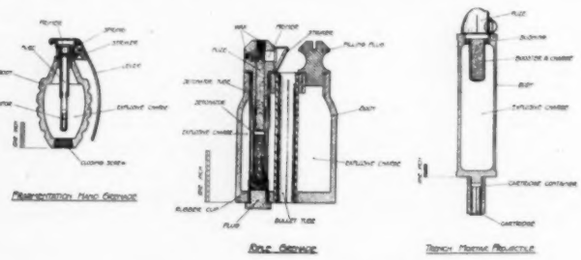
The problems entering into the loading of boosters are similar to those met in loading shell, as a booster may be taken as being a small loaded shell inside the main charge of the projectile. The question of cavitation, however, does not enter as the booster charge (except in the case of the outer charge in double-walled gas boosters) is always made of compressed crystalline explosive. Exudation also of the booster charge does not occur as the



Types of Artillery Ammunition

booster charge is of pure TNT or of tetryl which does not tend to exude.

Fuze loading and assembly is too large a topic to be discussed in a satisfactory manner in this present article. The general precautions to be taken are determined by the same principles as obtain in the case of shell and booster charges, special care, however, being taken in consequence of the extremely sensitive explosive, mercury fulminate, used in detonators. Detonators for fuzes usually consist of copper cups in which the explosive charge is compressed and afterwards closed by means of a closing disc over which the top part of the copper cup is crimped. No explosive must be present between joints, and all traces of the sensitive mercury fulminate must be removed from the outside of the detonators. The detonators upon completion are examined carefully (in the



Types of Trench Warfare Ammunition

case of detonators for armor-piercing fuzes by means of a microscope) to make certain that no cracks or modifications of the metal exist which might cause premature explosion due to the nipping of explosive between joints. The time element in fuzes is usually formed of black powders or of some powder of a similar composition placed so as to interrupt the transmission of the flash from the primer to the detonator. Extreme care must be taken to have this powder of the correct composition, and, in the case of small pellet delays of .05 or .15 second, to insure that the pellet does not break up on set-back (or set-forward in the case of armor-piercing projectiles), or be so weakened as to allow flashing through of the primer detonation with resulting instantaneous effect. Assembly also demands particular attention in fuzes, as the parts are so small, and malfunctioning is so readily brought about.

The Practice of Loading and Assembling of Ammunition

The Main Charge: The ordinary shell used in mobile artillery are of the point-fuzed type; that is the fuze is in the nose of the shell. These shells, during the war, were loaded chiefly with 80/20 amatol, a mixture of 80 parts of ammonium nitrate and 20 parts of TNT this explosive being used because of the lack of sufficient quantities of TNT. In the case of small caliber shell such as the 75 mm., 50/50 amatol was used consisting of 50 parts of ammonium nitrate and 50 parts TNT. At the present time all shell are being loaded with TNT. 80/20 amatol is prepared by crushing and drying ammonium nitrate, melting TNT in steam-jacketed kettles and mixing these two components in the required quantities in a steam-jacketed mixer. The result is a product resembling soft brown sugar and is usually at a temperature of 100°C to 105°C at the time of use. This material may be tamped into the shell by the use of hammer and mallet, but during the war was put into the shell by means of the screw filling machine, this machine being rapid in action and facilitating production. The screw filling machine consists of a hopper to hold the amatol and extending from the hopper in a horizontal position a sleeve containing a rotating worm. The shell in a horizontal position mounted on a wheel carriage is pushed so that the worm and sleeve enter to within one or two inches of the bottom when the machine automatically starts and the amatol is fed into the shell by the rotating worm. After a certain quantity of amatol has been fed into the shell the resistance to the entrance of more amatol causes the carriage with its shell to retreat from the hopper until at a certain point the machine is automatically stopped. The shell is then backed away from the end of the sleeve and is found to be full of amatol with the exception of a cavity left by the sleeve and worm, the depth of this cavity having been previously decided by adjustment. The shell backs off in a direction against the resistance of counterweights attached to the carriage by means of a steel rope, these counterweights being raised as the carriage with its shell retreats. The desired density is obtained by variation of the quantity of TNT in the amatol, more TNT giving a higher density, and also by varying the counterweights, heavier counterweights giving higher densities. This machine is very rapid and sure in its action, the necessary adjustments having to be made for the first two or three shell made from each lot of amatol. 80/20 amatol is not so sensitive to detonation as is TNT and for this reason the cavity in the charge is made about one-fourth inch larger in all directions than the size of the booster. After cooling of the amatol charge, liquid TNT is poured into the cavity, after which an empty booster or dummy booster is screwed in the nose of the shell, and the shell allowed to remain for some time until the TNT has solidified. On withdrawing the booster, a cavity is left of the correct dimensions. The shell is then completed by carefully cleaning the threads of all explosive and inserting the loaded booster.

In the case of shell loaded with 50/50 amatol or with TNT the method found to give best results is as follows: 50/50 amatol or TNT is poured into the shell in quantities depending upon the size of the shell, the liquid explosive in the case of straight TNT being cooled to a temperature just a little above the setting point so as to reduce contraction to a minimum and so as to obtain smaller crystals in the charge and hence higher density. With small caliber shell, such as the 75 mm., one pouring is sufficient. In the case of 155 mm. shell, two or three pourings are used. This method of loading by increment is necessary to prevent excessive cavitation in the nose of the charge, the practice being to break down the cavities in the head of each increment before adding the next. The last charge is poured in so as to reach a point several inches high in the funnel used during the pouring operation. The neck of TNT is readily broken and the funnel containing the riser with most of the cavitation is removed; the cavity for the booster is afterwards drilled, the threads cleaned and the booster inserted.

Armor-piercing projectiles are loaded with explosive D by means of the hydraulic press. The crystalline explosive D is consolidated into the shell by preliminary hand tamping followed by compression by means of the hydraulic press in increments the number of which depend upon the caliber of the projectile. Extreme care is taken that all parts of the charge are at as near as possible the same density. The greatest difficulty is obtained in consolidating the first increment sufficiently to obtain the correct density in the nose of the charge. It will be apparent that this portion of the charge in the case of an armor-piercing projectile is of most importance, as it is the portion which is subjected to the extreme shock of the set-forward of the

whole column of explosive in the projectile when impact on armor plate takes place. Extensive experiments have had to be carried out to develop a method of loading armor-piercing projectiles with explosive D so that the desired density is obtained in all parts of the charge.

In shrapnel ammunition the bursting charge consists of black powder, the remainder of the interior of the shell being filled with balls and a matrix of rosin, these balls being projected through the air on the explosion of the black powder charge. This black powder charge is not pressed in but is consolidated in the base of the shell by vibration. Special precautions must be taken in the case of shrapnel ammunition that black powder is not present in the screw threads. To accomplish this, the bottom of the flash tube is sealed by means of a fiber cup and a shellaced disc of cloth and the fuze threads are carefully cleaned.

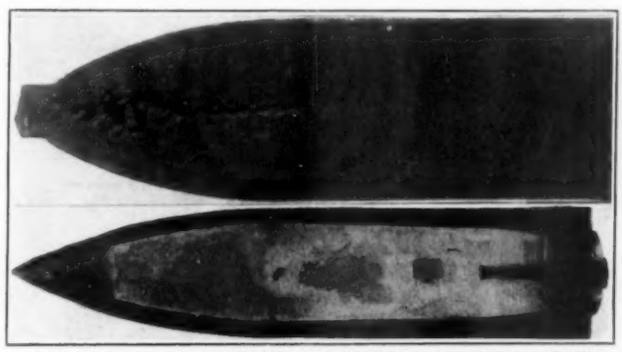
Trench Warfare ammunition as used with mortars is loaded with various explosives. In the case of the 3-inch Stokes Trench Mortar shell a nitro-starch explosive is used. 80/20 and 50/50 amatol were used during the war in the case of the 6-inch and 240 mm. Trench Mortar Shell. In view of the absence of severe set-back in firing this Trench Mortar ammunition, high density of the nitro-starch explosive and amatol used is not required. Sufficient care, however, is taken to avoid any carelessness of loading, the operators being held rigidly to the densities prescribed. In the case of 3-inch Stokes Trench Mortar shell the nitro-starch is tamped in by means of a heavy copper tool, the quantity of nitro-starch necessary to obtain the required density being poured slowly into the shell while tamping is proceeding. Six-inch and 9.2-inch Trench Mortar Shell were loaded in the case of 80/20 amatol on the screw filling machine in exactly the same way as were artillery shell. This ammunition is now loaded with TNT by casting in the same way as with artillery shell.

Hand grenades are loaded with nitro-starch or some similar explosive, in the powdered form, the required quantity placed in the hand grenades and consolidated by vibration on a table for a definite time previously ascertained necessary, or they may be vibrated while on a conveyor belt, the time taken for their transportation from the point of filling to the end of the belt being the time necessary for effective consolidation of the charge. In the case of hand grenades, as no ill usage other than the ordinary shocks of transportation is applied, no special precautions are necessary other than the obtaining of the required density of the charge and the freedom of the screw threads from explosive. Rifle grenades, however, having to be ejected from the Tromblon attached to the rifle, are subjected to shock, and are therefore loaded with compressed TNT, particular care being taken in the loading as regards density and freedom from explosive of the screw threads.

Bombs for use by Aircraft are loaded with 80/20 amatol or with TNT in much the same way as are shell. The large quantities of explosive used in the larger bombs make production of these loaded bombs relatively slow as so much time has to be allowed for the cooling, solidification, and the breaking down of cavitation of each increment of explosive.

Booster Charges: Boosters are loaded with tetryl. They were originally loaded with tetryl around the fuze socket and TNT to fill the remainder of the booster, but this method was not found as efficient as the complete loading of the booster with tetryl. There are two principal methods of loading boosters. First, by measuring the quantity of explosive by weight or volume and compressing this into the booster in one pressing by means of a hydraulic press fitted with a plunger of the same size as the cavity in the booster charge to be subsequently filled with the bottom portion of the fuze. The other method is to consolidate pellets of explosive in the hydraulic press and afterwards insert these pellets into the booster with annular pellets at the top to form the cavity for the fuze socket. The second method is preferred, as in this case more homogeneous densities are obtained, it being impossible to obtain the same density through a column of material on compression, there being a range of density through the column, the highest density being on top. By the pellet method of loading boosters the booster column is pressed in sections and thus the range of density is less extreme.

Care has to be taken in the case of explosive charges that the part of the charge in which detonation is initiated is not at too high a density as sensitiveness to detonation decreases with increase in density. In the first method of loading booster outlined above this fault of explosive at high density surrounding the fuze exists. This fault is obviated in the case of pellet loading by inserting the pellets



Above: Enlargement of Sectionalized TNT Charge for 155-mm. Shell Showing Cavitation

Below: 10-inch Shell Loaded with Explosive D Sectionalized to show Defective Loading

upside down in the booster casing so that the softer part, that is the part at lower density, is on top. Boosters for artillery ammunition, trench warfare and aircraft ammunition are much alike, the chief difference being in the matter of density, boosters of lower density being used in ammunition where set-back is not severe or not to be considered.

General Observations

In consequence of the lack of space the above treatment of the subject of loading and assembly of ammunition is necessarily lacking in detail. An effort has been made to deal with the main points of the subject so as to give the reader an idea of the problems facing the loader of ammunition. The problems dealt with are those having reference to the mechanics of production of ammunition of high quality. Unfortunately there are other problems of little less importance entering into the manufacture of ammunition dealing particularly with the precautions to be taken to safeguard the workers against risk due to explosion and against poisoning due to the manipulation of explosives. All operations are isolated within strong concrete or steel walls so as to limit the danger to the personnel dealing with one operation. Where possible the operators work with readily adjustable obstructions between them and the explosive so as to be out of danger in case unexpected blast takes place. TNT also is somewhat poisonous, particularly in the case of fumes given off from it when in the melted state, and plants loading ammunition have elaborate ventilating installations as a necessary part of their equipment.

New "Four-Point-Seven" Guns

A Comparative Study of Pre-War and Post-War Corps Artillery Guns

By

B. P. JOYCE

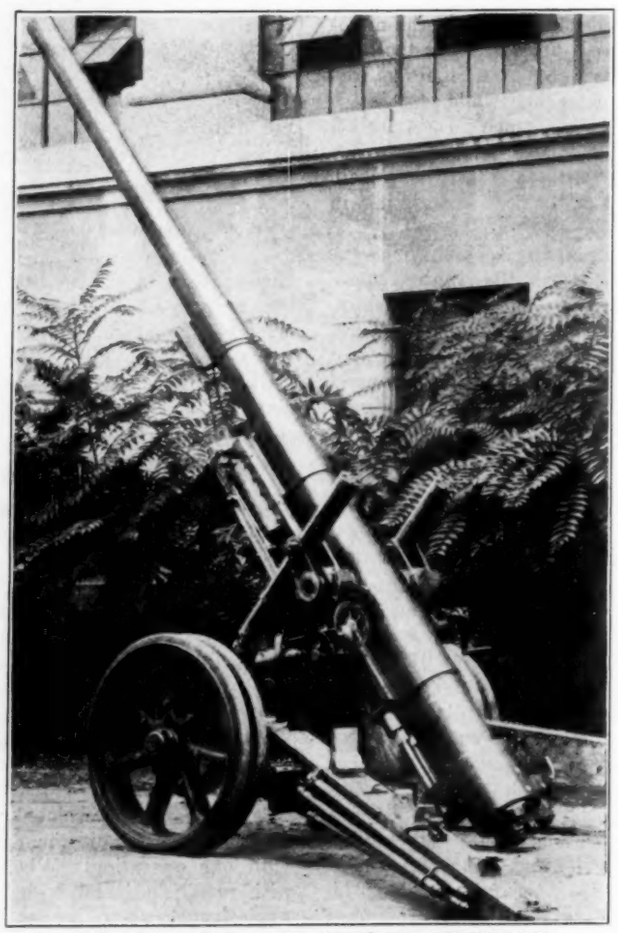
Member A. O. A.

SHORTLY after the Armistice was signed, there was convened by War Department order a Board of Officers representing the Artillery and the Ordnance Department, for the purpose of making a study of the armament, calibers and types of matériel; kinds and proportion of ammunition, and methods of transportation of the artillery to be assigned to a Field Army. After much study of existing and proposed armament of the armies of all nations, the Board drew up definite specifications from the user's standpoint of all types of ordnance required for the various units of a Field Army.

For Corps Artillery, they specified as the *ideal* armament a gun of caliber between 4.7 inches and 5 inches, to be mounted on a carriage permitting a vertical arc of fire of at least 80 degrees, and a horizontal arc of fire of 360 degrees; to fire a projectile weighing not over 60 pounds at least 18,000 yards. To serve as a companion piece to the gun and have at least its mobility and yet provide a heavier projectile, the Board specified an *ideal* howitzer of about 155 mm. caliber to be mounted on a carriage permitting a vertical arc of fire of at least 65 degrees and a horizontal are of fire of 360 degrees; to fire a projectile weighing not over 100 pounds at least 16,000 yards.

The Board deemed it particularly desirable that both the Corps gun and Corps howitzer just described should be so constructed as to permit their being assembled to the same recuperator system, carriage and running gear.

While the Board did not attempt to indicate how these *ideal* requirements should be met, nor even to intimate that they could be met in all cases, the Ordnance Department proceeded to design pieces of ordnance to meet the approved requirements insofar as possible. The requirements as to interchangeability of mounting either the 4.7 gun or the 155 mm. howitzer on the same identical carriage necessitated compromises which of course, yielded a combination carriage not as satisfactory for either the gun or the howitzer as if individual carriages had been designed for each weapon. To determine exactly what had been gained and what had been lost in seeking this interchangeability a carriage designed for mounting the 4.7-inch gun only is now under manufacture and a carriage designed to mount the 155 mm. howitzer only may later be manufactured if found desirable and funds are available. Both of the post-war types are vastly superior to the original 4.7-inch gun model of 1906, which was standard equipment in our Army at the outbreak of the World War.



4.7-Inch Gun and 155-mm. Howitzer Carriage, Model of 1920
4.7-Inch Gun Mounted on Combination Gun-Howitzer Carriage
Left Rear View. Zero Traverse. 52 degrees elevation

The 4.7-inch Gun Carriage, Model of 1906, was designed to be horse-drawn and therefore its weight was strictly limited. In view of these limitations, the carriage was restricted to a total traverse of 8 degrees and a maximum elevation of 15 degrees, these movements being about the same as in other contemporary types. The new experimental carriages of this type propose to use if possible a somewhat better grade of gun steel, which permits a reduction in the total weight as compared with that for a gun of the same power, but of lower grade steel. The new guns being of much greater power, the weight of the new matériel is considerably greater than that of the old, but this is permissible since it will be motor-drawn. The accompanying diagram will clearly illustrate the greater range and field of fire of the new matériel. The comparative muzzle energies of the old and new matériel are also indicated.

The combination 4.7-inch Gun—155 mm. howitzer carriage, Model of 1920, was designed and built to meet as far as possible all of the *ideal* requirements set forth above. The howitzer specified, being the more powerful weapon, controlled the design of the carriage. The non-interchangeable carriage for the gun only (4.7-inch Gun Carriage, Model of 1921 E), seeks to meet all *ideal* requirements excepting that it shall be capable of mounting a 155 mm. howitzer without alteration, thus permitting reduction of weight to correspond

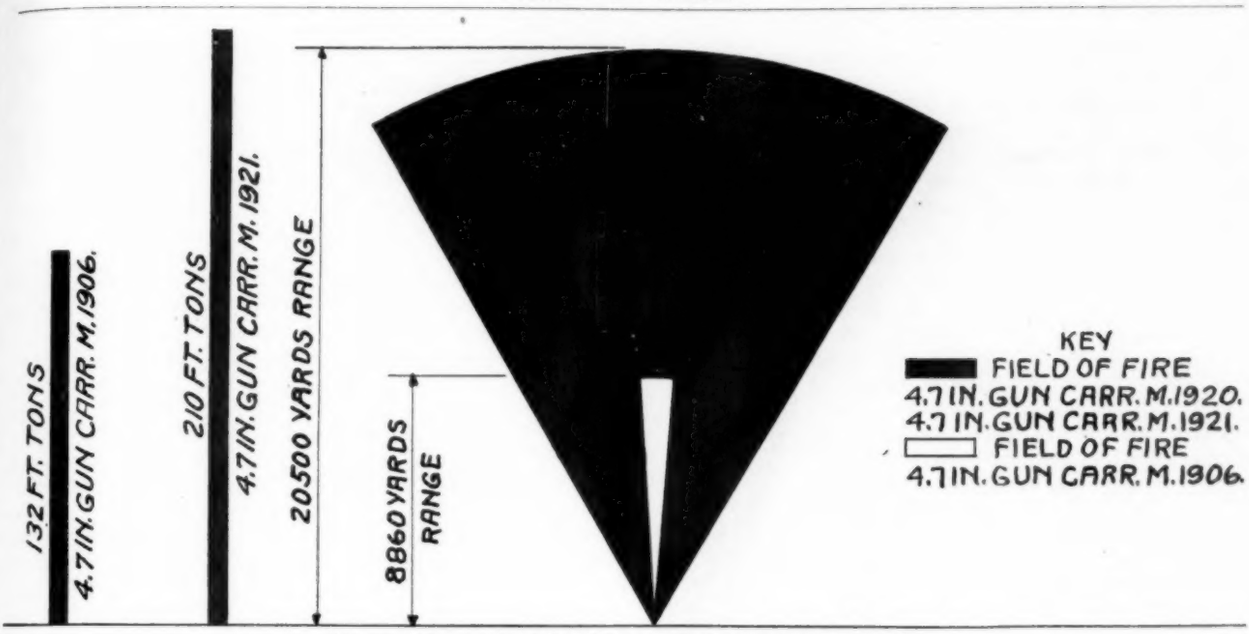

132 FT. TONS
4.7 IN. GUN CARR. M. 1906.
210 FT. TONS
4.7 IN. GUN CARR. M. 1921.
20500 YARDS RANGE
8860 YARDS RANGE
KEY
FIELD OF FIRE
4.7 IN. GUN CARR. M. 1920.
4.7 IN. GUN CARR. M. 1921.
FIELD OF FIRE
4.7 IN. GUN CARR. M. 1906.

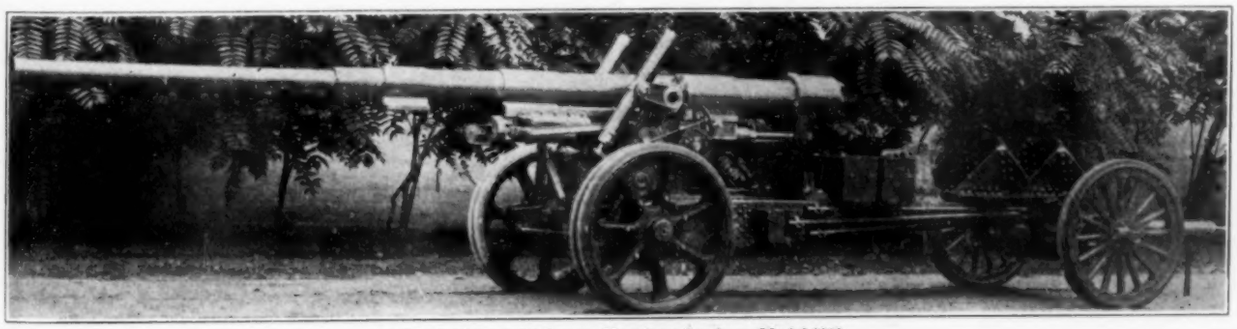
Diagram of Comparative Fields of Fire and Muzzle Energies in Foot-Tons

with the less powerful weapon it is designed especially to mount.

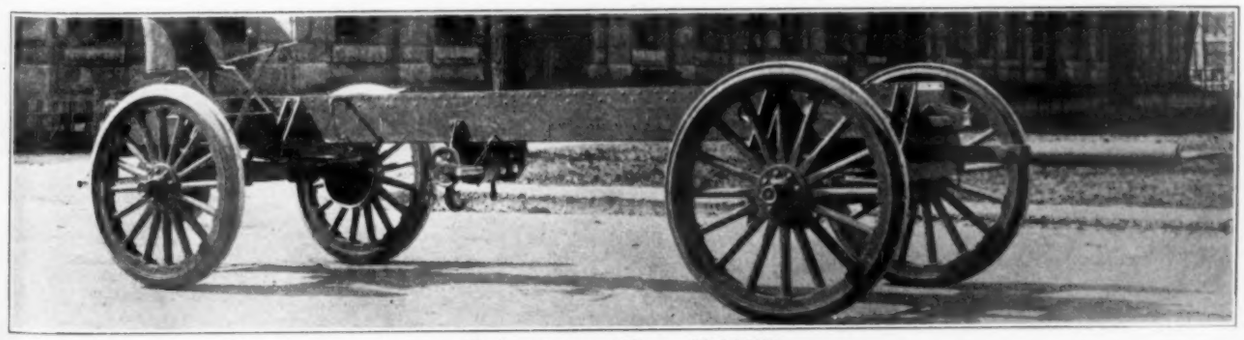
As the combination carriage, Model of 1920 is motor-drawn, it is spring supported and rubbed tired, and a transport wagon is provided to carry either gun or howitzer so that the load may be split for long hauls. This transport vehicle is known as the Medium Transport Wagon, Model of 1920. The carriage is provided with a band brake so arranged that it can be set when firing, or operated from the trail seat when traveling. The carriage is of the split-trail type permitting a total traverse of 60 degrees and equalization is obtained by means of an axle pivot. Owing to the high elevation of 65 degrees at which this piece can be operated, it is provided with a quick-return mechanism, the function of which is to return the gun from the firing position to the loading position (horizontal) more promptly than would be possible by using the regular elevating mechanism, thus materially increasing the rate of fire.

The recoil mechanism is hydro-pneumatic. The tipping parts are balanced at the trunnions by means of pneumatic equilibrators. The trunnions are fitted with roller bearings. The gun is of high grade steel built-up and has a screw block. The sight and the traversing and elevating hand-wheels are located upon the left side of the carriage. The quick-return lock and the quick-return crank are located upon the right side of the carriage.

A removable winch of 25 pounds weight is provided with the carriage to pull the piece on and off the carriage and to retract the piece into its traveling lock for short hauls. The limber (Medium Carriage Limber, Model of 1920), is a two-wheeled spring supported platform to receive the trail ends. The detachable spades, the traveling



4.7-inch Gun and 155-mm. Howitzer Carriage, Model 1920
Gun mounted on carriage and limbered for travelling short distances



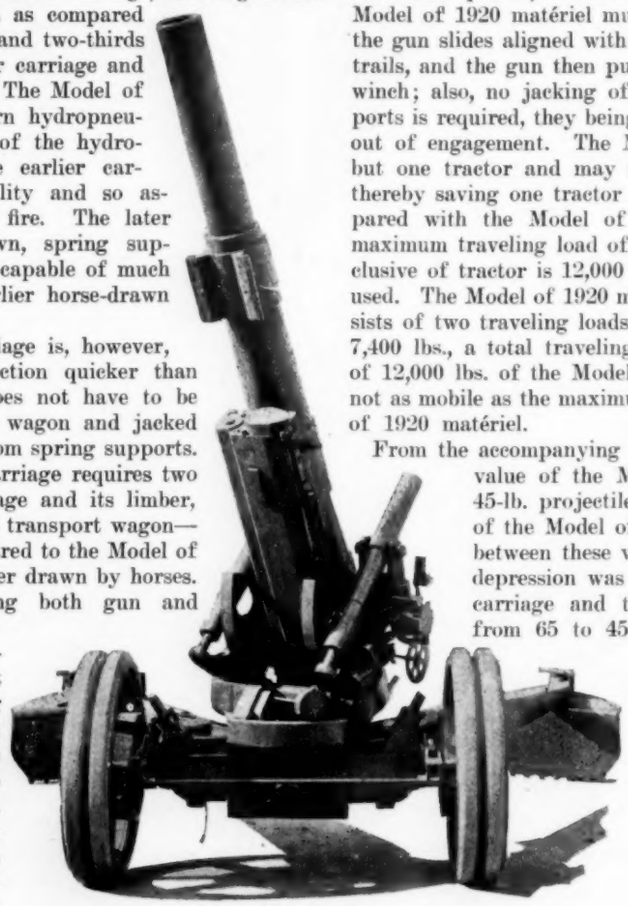
Medium Transport Wagon, Model 1920
The gun is loaded on this wagon for travelling long distances

lock, the lighting equipment and tool chests are carried upon the trails.

The advantages of the Model of 1920 carriage over the Model of 1906 are increased range and increased field of fire without disturbing the wheels and trail. It fires a 50-lb. projectile 20,500 yards as compared with a 45-lb. projectile ranging 8,860 yards—an increase in range of almost two and one-half times with a heavier projectile. Incidentally, this range exceeds the *ideal* requirements of the Westervelt Board by 2,500 yards. The Model of 1920 carriage has a total traverse of 60 degrees without shifting wheels or trail as compared with a total traverse of 8 degrees for the Model of 1906 carriage, covering a field of fire of 70 square miles as compared with a field of fire of one and two-thirds square miles for the earlier carriage and with a heavier projectile. The Model of 1920 carriage has a modern hydropneumatic recuperator in lieu of the hydrospring recuperator of the earlier carriage, which insures stability and so assures greater accuracy of fire. The later carriage being motor-drawn, spring supported and rubber tired is capable of much greater speed than the earlier horse-drawn vehicle.

The Model of 1906 carriage is, however, capable of getting into action quicker than the later carriage as it does not have to be mounted from a transport wagon and jacked to a solid firing position from spring supports. Also, the Model of 1920 carriage requires two tractors, one for the carriage and its limber, and one for the gun and its transport wagon—an elaborate outfit as compared to the Model of 1906 gun carriage and limber drawn by horses.

The object of mounting both gun and howitzer upon the one carriage was to facilitate production, but as a transport wagon is necessary to bring the loads within 12,000 lbs., it was found expedient to design the 4.7-inch Gun Carriage, Model 1921. As plunging fire is not a function of a gun carriage, 45 degrees elevation was specified for this carriage, which permitted a gun, carriage and limber to be designed within the weight of 12,000 lbs., thereby obviating the necessity of a transport wagon.



4.7-inch Gun and 155-mm. Howitzer Carriage, Model 1920
155-mm. Howitzer Mounted on Combination Gun-Howitzer Carriage

The gun for this carriage is of high-grade steel built-up. It weighs but 3,700 lbs. as compared with 4,200 lbs., the weight of the gun for the Model 1920 carriage. It is provided with a screw block of the swing type equipped with an equilibrator so that the piece may be loaded at all elevations. The recoil mechanism is hydro-pneumatic. A rack underneath the gun to mesh with a cranked pinion, supported by bearings on the rear end of the cradle, provides a simple retracting mechanism. A quick-acting connection is provided between the gun lug and the piston rod by means of a sliding key. The tipping parts are balanced at the trunnions by means of pneumatic equilibrators. The sight and the elevating and traversing handwheels are located upon the left side of the carriage. The elevating and traversing parts are entirely supported upon ball and roller bearings, thereby insuring minimum hand-wheel loads. Improved spring supports on this carriage obviate the necessity of jacking up the carriage when limbering, which should greatly facilitate this maneuver. The other features of this carriage and its limber are similar to the Model of 1920 carriage and its limber.

The advantages of the Model of 1921 carriage over the Model of 1920 carriage are principally in shortened time to get into action and lessened road-space en route. It can get into action much more quickly owing to the fact that its gun is never withdrawn from its cradle when traveling and only needs to be moved into battery by means of a rack and pinion, whereas, the transport wagon of the Model of 1920 matériel must be aligned with the carriage, the gun slides aligned with the cradle ways by hoisting the trails, and the gun then pulled into battery by means of a winch; also, no jacking of the carriage from spring supports is required, they being so designed as to swing in and out of engagement. The Model of 1921 carriage requires but one tractor and may not require a transport wagon, thereby saving one tractor and a transport wagon as compared with the Model of 1920 matériel. However, the maximum traveling load of the Model of 1921 matériel exclusive of tractor is 12,000 lbs., transport wagon not being used. The Model of 1920 matériel exclusive of tractors consists of two traveling loads, one of 10,300 lbs., and one of 7,400 lbs., a total traveling load of 17,700 lbs. The load of 12,000 lbs. of the Model of 1921 matériel is, of course, not as mobile as the maximum 10,300 lbs. load of the Model of 1920 matériel.

From the accompanying table it is seen that the relative value of the Model of 1920 carriage using a 45-lb. projectile is 1.09 as compared with 1.23 of the Model of 1921 carriage. The difference between these values is due to the fact that no depression was required on the Model of 1921 carriage and that its elevation was reduced from 65 to 45 degrees. The Model of 1920 gun and carriage was designed for a 45-lb. projectile, and when later a 50-lb. projectile was determined upon, certain sacrifices had to be made as indicated by the values 1.00 and 1.09. In connection with the 1.02 value of the Model 1906 carriage, it must be borne in mind that the carriage has a very moderate traverse and elevation and its real value is considerably less, as indicated by comparative fields of fire.

RELATIVE VALUES

Based on muzzle energy of projectile per lb. of gun and carriage.

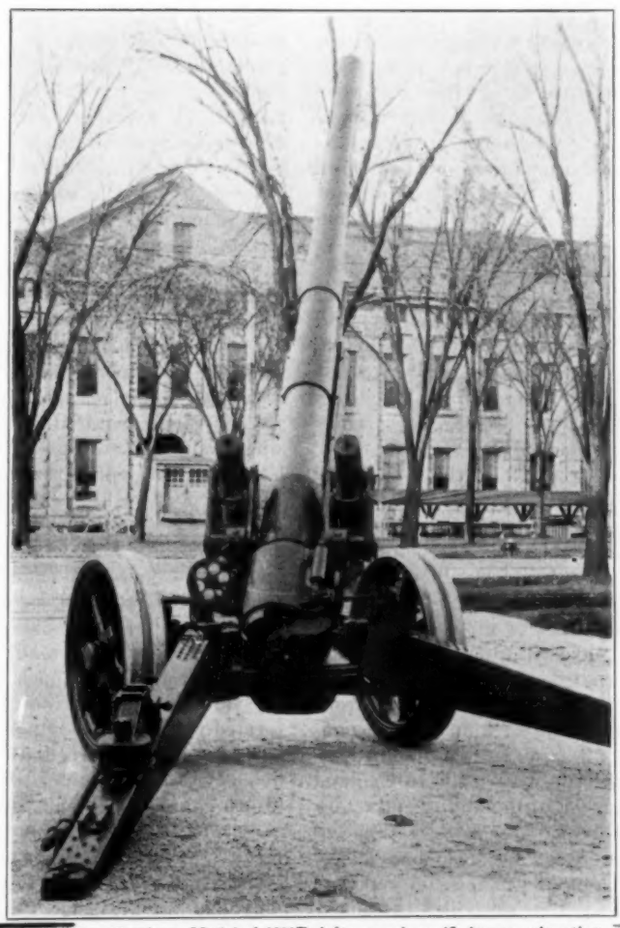
	4.7 In. Gun Carr. Model 1906	4.7 In. Gun Carr. Model 1920	4.7 In. Gun Carr. Model 1920	4.7 In. Gun Carr. Model 1921
Weight of projectile—lbs.	45	45	50	50
Muzzle Velocity ft.-seconds	2050	2700	2450	2450
Energy of projectile—ft.lb.	2,950,000	5,120,000	4,700,000	4,700,000
Weight gun and carr.—lbs.	8,068	13,000	13,000	10,600
Elevation ——degrees	—5+15	—5+65	—5+65	0+45
Traverse ——degrees	8	60	60	60
Energy projectile per lb. Gun and Carriage—ft.lb.	367	393	362	443
Relative value ——	1.02	1.09	1.00	1.23

As to mobility, both the combination gun-howitzer carriage (4.7-inch Gun and 155 mm. Howitzer Carriage, Model of 1920), and the carriage which is designed especially for mounting the gun and is not intended to mount the howitzer also (4.7-inch Gun Carriage, Model of 1921 E), can be drawn by tractors at speeds sufficiently high to enable them to keep well up with all other tactical elements of an Army Corps. True their weights are considerably greater than the pre-war 4.7-inch Gun Carriage, Model of 1906, but the substitution of the gasoline engine for draft horses has produced not only ample power to move the much heavier weights of the new matériel, but to move these heavier loads at much greater speeds than ever could have been possible even for the lighter pre-war matériel under the animal-drawn transport system. The mobility problem may, then, be considered as satisfactorily solved.

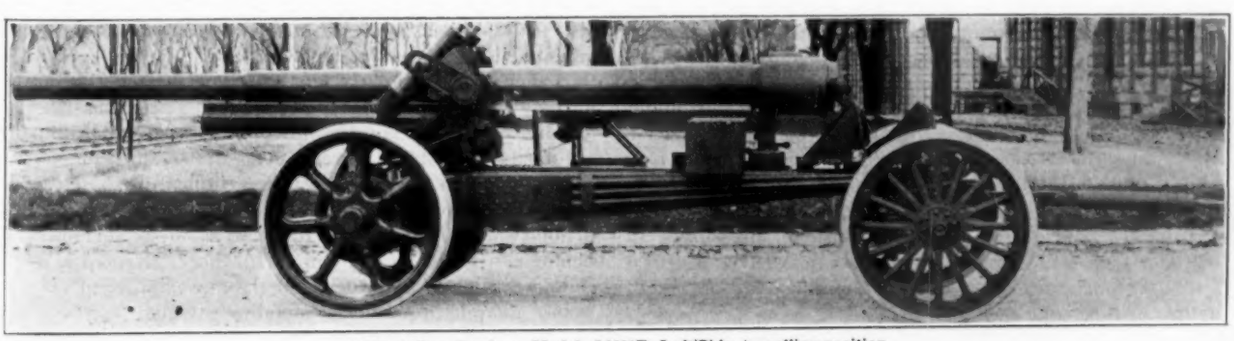
In one respect alone do the post-war guns fall below the *ideal* requirements of the Westervelt Board, namely, in not providing 360 degrees traverse of the gun upon the carriage, or all-around fire. This requirement was not specifically emphasized by the Board, and there is some doubt as to whether the sacrifices that would have to be made in order to obtain it would not adversely affect other requirements concerning which there is no division of opinion as to desirability. All around fire would probably require the adoption of a pedestal mount, which would in turn need a wide, stable platform under-slung from two axles, as has been found necessary in the anti-aircraft types of gun carriages. All ordnance design is a compromise, or, rather, a series of compromises, and the best that can be said of a given design is that it has utilized the most recent development of science and engineering to yield the most effective weapon within a given limit of weight. Judged from this standpoint, both of the new 4.7-inch guns described in this article are eminently satisfactory. Metallurgy has contributed stronger steel for a given weight—a more powerful weapon per pound of gun. Compressed air in the hydro-pneumatic recuperator has displaced the heavy spring columns of earlier recoil and counter-recoil systems—a more efficient mechanism per pound of carriage. Researches in aerodynamics point out the best form of ogive, location and profile of rotating band, and degree of boat-tailing—a more effective missile per pound of projectile. Automotive engineering has contributed increased tractive power, thus permitting increased maximum weight of the complete unit, and correspondingly increased power over and above that attributable to perfection of design. It only remains to determine whether or not the principle of interchangeability between gun and howitzer is worth adhering to, in the light of some of the advantages already demonstrated for the principle of designing each weapon to fulfill its own particular requirements, and this is a question for the using services to answer after extensive tests under severe field service conditions.

CHARACTERISTICS

	4.7 In. Gun Carr. Model of 1906	4.7 In. Gun Carr. Model of 1920	4.7 In. Gun Carr. Model of 1921
Length of gun in calibers	27.5	47.5	42.
Muzzle velocity, shell, normal—f.s.	2,050	1,850	1,850
Muzzle velocity, shell, super—f.s.	----	2,450	2,450
Muzzle velocity, shrapnel	1,700	not determined	
Maximum range at elevations obtainable on carriage—yards	8,860	20,500	20,500
Maximum elevation possible—degrees	−5+15	−5+65	0+45
Traverse—Total—degrees	8	60	60
Weight of shell—lbs.	45	50	50
Weight of shrapnel—lbs.	60	50	50
Normal length of recoil—in.	70	48-21	48
Weight of gun and breech mech.—lbs.	2,688	4,200	3,700
Weight of gun, carr. and limber—lbs.	9,818	14,500	12,000
Weight of gun and carr.—lbs.	8,068	13,000	10,600
Weight of carr. and limber—lbs.		10,300	
Weight of gun and transport wagon—lbs.		7,400	



4.7-inch Gun Carriage, Model of 1921E; left rear view, 45 degrees elevation, 30 degrees traverse, firing position



4.7-inch Gun Carriage, Model of 1921E; Left Side, travelling position

Smokeless Powder

By

C. G. STORM

Member A. O. A.

THE importance of smokeless powder is often overlooked, even by those who are interested in the development of new types of artillery and small arms. When an improved type of gun is designed and constructed, it is naturally expected that a suitable propellant will be ready to meet its particular ballistic requirements. For example, it is decided to construct a new caliber .50 machine gun with a bullet six times as heavy as the service caliber .30 bullet, and with a velocity such as to enable it to penetrate tank armor. The volume of the carriage case which must hold the propellant charge is decided upon, and the powder manufacturer is expected to produce a powder which will meet these requirements and not produce a pressure in the gun greater than that prescribed by the designers. Furthermore, the allowable variation in pressure and velocity are very small, in order that the greatest possible accuracy may be obtained; there must be a minimum of smoke visible by day and of flash visible by night in order that the position of the piece may not be revealed; the powder must be chemically stable to ensure its keeping qualities, non-hydroscopic to insure ballistic stability, and must have a sufficiently low temperature of combustion so that it may not cause excessive erosion of the gun. A brief review of the history of the development of smokeless powder may be of interest as serving to show how it has been possible to meet such requirements.

From the date of the earliest records of the use of fire arms up to the middle of the 19th century, a period of about 500 years, black powder stood alone as the universal propellant with practically no change in its composition. Schoenbein discovered in 1845 that when ordinary cotton was treated with a mixture of nitric and sulphuric acids, a striking change occurred in the properties of the cotton without any appreciable change in its physical appearance. It had been converted into a highly inflammable material which offered promise as a substitute for black powder in fire arms.

This discovery started experimental work in various countries, and within a short time attempts to manufacture the so-called gun-cotton on a large scale were made in England and France. An explosion of the still unfinished factory at Faversham in 1847 stopped the English investigation and two explosions in France the following year had a like effect in that country. The German Commission reported unfavorably, pronouncing guncotton unstable, of uncertain force, and too expensive.

All investigations were discontinued except that of Von Lenk in Austria. He concluded that previous failures had been due to lack of stability resulting from incomplete purification, and his improved process included purification of the raw cotton by boiling in dilute caustic potash, washing and drying. His nitration product was washed in running water from 3 to 6 weeks in order to free it from excess acid. Attempts were made to use this improved guncotton in fire arms in the form of loose fibers or spun into strings or cords but the results were disastrous owing to the bursting of the barrels from the rapid rise of pressure. In 1862 and 1865 two magazine explosions in Austria, ascribed to spontaneous ignition of guncotton, stopped further manufacture in that country.

In 1864, however, Abel in England, revolutionized the process of purifying guncotton by pulping the nitrated product, or cutting it up into such short lengths and fragments that the acid lodged in the cellular interior of the hollow tubular cotton fibers could be easily removed by washing. Abel's object in pulping his product was, however, widely different from the result obtained. He had hoped by compressing the pulped material into compact masses of uniform size and shape, to control its speed of combustion and render it suitable for use in guns. Compression failed, however, to produce the desired result of regulating the rate of burning. Abel then went a step further, by granulating his pulped guncotton by means of solvents, but although he patented this process, failed to carry it to practical success.

There was ample reason for the determined efforts that were being made to produce a satisfactory propellant from nitrocellulose. It burned with practically no smoke or residue and possessed about three times the energy of black powder. The improvements made in fire arms at this time demanded a better propellant than black powder. Rapid fire weapons could not give the best results without greater freedom from smoke and from residue in the bore. The reduction in caliber and increase in rifling necessary for greater range required powder of greater energy. Magazine small arms, machine and rapid fire guns demanded a less bulky propellant than black powder.

Attempts to meet some of these requirements with black powder consisted in compressing it into larger grains of greater density and definite shape. The experiments conducted by General Rodman of the Army Ordnance Department, in 1857 to 1869, resulted in the adoption of definite sized grains for each size of gun, some of which were perforated to give increased burning surface. These black powder grains were much larger than had been used and the various types were styled "pebble," "mammoth," "perforated prismatic" and "perforated cylindrical." Further efforts were made to regulate the combustion of black powder by changes in its composition. For example, partially burnt, brown charcoal was substituted for black charcoal, producing the brown prismatic or "cocoa" powder. This gave better results for large guns because larger charges could be used giving higher velocities without excessive pressures.

It had been assumed that black powder burned under pressure in the gun in parallel concentric layers, just as it did in open air, except at a higher rate. Sarrau later showed this hypothesis to be in error. Vieille in 1884-1885 also showed that even the brown prismatic powders were quickly disintegrated under the rapid rise in pressure, so that there was no longer any relation between the rate of burning and the original form of grain. He was the first to point out that gelatinized nitrocellulose burned with great regularity in parallel layers, even under the influence of sudden increase in pressure; thus indicating a means of definitely controlling the rate of combustion of propellants.

Somewhat prior to Vieille's work, however, Edward Schultze, a Prussian Captain of Infantry, invented a partly colloided smokeless powder made from a mixture of nitrated wood, nitro-hydrocarbons, metallic nitrates and sulphur,

granulated and superficially gelatinized by spraying with acetic ether. About the same time Reid and Johnson in England patented E. C. Powder, made in a similar manner from nitrocellulose pulp. A similar powder is made commercially at the present time. These powders were particularly adapted for shot guns and small arms of low velocity. Their rate of burning was rapid and only partly controlled, rendering them unsatisfactory for use in rifles.

About 1886 Vieille placed the art of smokeless powder manufacture on a real foundation by producing the first thoroughly colloided nitrocellulose powder in the form of square flakes of uniform size and thickness. In 1889 Nobel invented his "Ballistite," composed of equal parts of nitroglycerine and collodion cotton—a grade of nitrocellulose forming a plastic mass with nitroglycerin, capable of being rolled and cut in flake form. In the following year Abel and Dewar patented "cordite," a mixture of guncotton and nitroglycerin, colloided with acetone and containing a small amount of vaseline. This plastic mass was pressed through dies in the form of cords of suitable diameter.

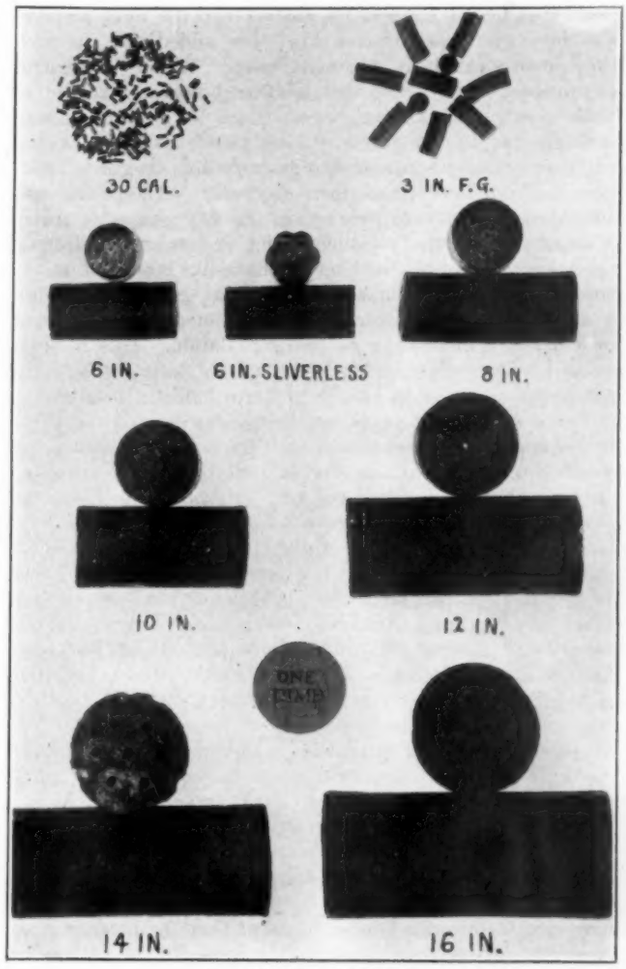
In 1890 Mendeléef, in Russia, followed up the work of Vieille, by pointing out a definite procedure by means of which a nitrocellulose of approximately uniform nitrogen content could invariably be obtained, which produced a maximum gas volume on combustion and which when thoroughly colloided with ether and alcohol in accordance with Vieille's procedure, could be graduated to form a satisfactory smokeless powder. He gave his nitrocellulose the name pyrocellulose, or "pyro" as it is called today. As early as 1893 Mendeléef's pyro powder was being manufactured on a large scale in Russia.

In the meantime, a laboratory was established in the United States at the Naval Torpedo Station, Newport, R. I., under Prof. Charles E. Munroe, and investigations were commenced to determine the most suitabe powder for the use of the United States Navy. In 1893 Munroe patented for the United States a powder called "Indurite," consisting of guncotton freed from lower nitrates by washing with methyl alcohol and colloided with nitrobenzene. The colloid was rolled into strips and dried or "indurated" by the action of steam or hot water, converting it into a hard, tough material. Following Munroe's resignation in 1894, Lieut. John B. Bernadou, U.S.N., took up the work and in 1897 he patented a powder composed of uniformly nitrated nitrocellulose (about 12.45 per cent nitrogen) colloided with ether alcohol. This is substantially the service powder of the United States at the present time and is also identical with that produced by Mendeléef in Russia.

About 1893 Hudson Maxim and Robert Schupphaus developed a perforated type of smokeless powder grain, which was the logical consequence of Rodman's early work on perforated black powder grains and the subsequent perforated prismatic cocoa powder. This type of grain was patented by Maxim in England in 1894. His powder was composed of 90 per cent colloid of guncotton and pyroxylin cotton with 9 per cent of nitroglycerin and 1 per cent of urea, acetone being used as a solvent for the guncotton. This powder was much less erosive than previous nitroglycerin powders containing 50 per cent or more of nitroglycerin, and the development of pressure was more sustained, since as the grains burned the size of the perforations increased maintaining a more nearly constant burning surface. This type of powder was termed "progressive." It was made in grains and tubes of various lengths containing from one to 19 axial perforations symmetrically arranged. Further development on perforated powder grains was carried on by F. G. DuPont and others in the United States, and the American rights to the Maxim-Schupphaus powder were acquired by the DuPont Company.

Subsequent to the highly satisfactory tests of the Maxim-Schupphaus powder in various guns at Sandy Hook in 1895 this type of double base powder was adopted by the Army while the Navy adhered to the nitrocellulose single base powder. This enabled a close comparison of the relative merits of the two types and in about 1900 the single base powder was adopted by the Army.

The use of double base powder for small arms was continued, however, for a number of years, as difficulty was encountered in securing with nitrocellulose powder the desired regularity of burning at low pressure. In about 1909 the Army adopted a single base .30 caliber powder developed by the DuPont Company, which contained a small amount of graphite added for the purpose of reducing temperature of combustion, and lubricating the bore. In a Service rifle this powder gave an accuracy life of 4,800 rounds as compared with 1,500 rounds for double base powder. This powder has a single perforated cylindrical grain, and is still in use.



Smokeless Powder Grains
It takes 375,000 grains of .30 caliber to make a pound, but only 12 grains of the powder for 16-inch guns

The nitrocellulose cannon powder used by both the Army and Navy of the United States was manufactured by the process originally patented by Bernadou, the American rights for which were sold by him to the DuPont Company. Briefly, the process of manufacture is as follows: Cotton, freed from oily materials and other impurities by boiling with dilute alkaline solution, followed by bleaching, washing, and drying, is nitrated by immersion in a mixture of nitric and sulphuric acids, converting it into nitrocellulose of the grade known as pyrocellulose or "pyro."

This product is freed from the spent acid, first by centrifuging, then by washing and boiling with water, then pulped to reduce it to very short fibers. The pulp is further purified by final boilings and washings to remove the last traces of acid and unstable products and is then separated from most of the water by centrifuging. It is then put in a dehydrating press, blocked, and alcohol forced through the block. The alcohol displaces the water and the block is left with a sufficient content of alcohol for the next process. The blocks are now broken up, ether added and the mixture incorporated in a dough mixer. Upon subsequent compression in a press, this mixture becomes a colloid or translucent, gelatine-like mass, which is finally pressed through dies in the form of long perforated strands and cut by mechanical cutters into grains whose length is about two and one-half times their diameter. These are now subjected to a drying process, in the first stages of which a large part of the volatile solvent is recovered. During the drying the colloid hardens to a horn-like mass and undergoes considerable shrinkage. The dried grains still retain a small content of solvent varying from about 1 per cent to 5 per cent depending on the granulation. This residual solvent content must be kept constant by means of air-tight containers in order to ensure uniform ballistic results.

For a number of years, smokeless powder for the U. S. Government was made almost entirely in private plants, the small Navy plant at the Torpedo Station being regarded only as an experimental project. However, in 1900, the Navy began the manufacture of smokeless powder on a large scale in its plant at Indian Head, Maryland, which was gradually enlarged in a few years to a capacity of about 10,000 pounds per day. In 1907 the Army completed a plant at Picatinny Arsenal, Dover, New Jersey, with a capacity of several thousand pounds per day. The manufacture of even as little as 25 per cent of the peace time requirement of powder in these two plants placed the Government in a position to thoroughly investigate the details of the process, and stimulated similar action by private manufacturers. Improvements in the methods of purification and stabilization were made which improved the quality of the powder and greatly reduced its cost.

No matter how thoroughly purified, nitrocellulose has an inherent tendency to undergo a gradual decomposition so that after a period of some years its ballistic qualities may have deteriorated to such extent that the powder is no longer fit for service. To avoid the necessity for destroying such powders, a process of re-working was developed, whereby the powder was finely ground, re-stabilized and made into new grains. This process has saved much deteriorated powder from destruction.

To counteract the tendency toward decomposition, various substances have been incorporated in the powder to serve as "stabilizers," by combining chemically with the gaseous "acid" products of decomposition as they are generated, thereby arresting decomposition in its incipiency. After exhaustive experiments, diphenylamine was adopted as the stabilizer in United States powder, and is still used in an amount of about 0.4 per cent of the powder. Its use is claimed to have practically doubled the life of the powder. The 5 per cent of vaseline used in Cordite exerts a similar influence.

An improvement in the drying process was developed in France which greatly reduced the time required for elimination of the solvent. By the air-drying method at 35-degrees to 40-degrees Centigrade several months were required for drying the larger sizes of grains. The new process accomplished this result in a relatively few days by immersing the powder in tanks of water, in which the solvent is soluble. When the water has absorbed the solvent it is drained off and the powder given a final drying in a circulation of warm air, which readily eliminates the remaining water. This process was largely used during the World War.

The Nash process of drying, devised by Mr. Nash, of the Hercules Powder Company, consists in immersion in alcohol for removal of the ether from the grains, then immersion in water for absorption of the alcohol. In less than 48 hours' treatment the powder is ready for the final air-drying for removal of the adhering water. This process was tried on a large scale with gratifying results, but has not been generally adopted.

Prior to the War, much experimental work had been conducted in Germany to develop processes for the preparation of cellulose from wood pulp as a substitute for the cotton used in powder manufacture. The success of this work is indicated by the fact that practically all of Germany's war supply of smokeless powder was necessarily made from wood pulp, there being no available supply of cotton. Methods have also been developed in this country for the purification of wood cellulose, and sufficient smokeless powder manufactured from such material to ensure the practicability of its use in case of necessity.

It has always been found necessary to use an igniting charge of black powder with a propelling charge of smokeless powder, because of the difficulty of securing uniform ignition of the latter by the flash from the primer alone. Theoretically, every grain of powder in a charge should be ignited simultaneously and be completely burned at the some instant. In fixed ammunition an ignition charge of 21, 49 or 110 grains of black powder is combined with a percussion cap in the form of a "primer," but in separate loading ammunition, where the charge is made up in a number of bags, a larger ignition charge is necessary. This varies from 3 ounces to 6 pounds depending on the size of the gun, and is at present used largely in the form of a single pad at the base of the rear section. Much experimental work has been done to determine the most suitable arrangement of the ignition charge. The "core" system, in which a small cylindrical core of black powder extends through the center of each bag, has many advocates, as has also the use of a separate pad at the base of each section. The latter system is the one used by the U. S. Navy. Various forms of readily-ignited fine-grained smokeless powder as an ignition charge have been proposed and tried out as a possible solution of the ignition problem.

Much development work has been done, and is still in progress, to eliminate the muzzle flash which is visible at a great distance especially at night and serves to disclose the location of a battery. This flash is characteristic of both single and double base types of powder. This flash is due to the ignition of inflammable gases (carbon monoxide and hydrogen) as they issue from the muzzle at a high temperature and mix with the oxygen of the air. The addition to the charge of substances which lower the temperature of the gases, or dilute them, may result in preventing their ignition. Thus, the Germans added potassium chloride or common salt to the powder charge and the French incorporated a small percentage of vaseline or other carbonaceous material, with the result that some reduction of flash was obtained. Experiments made in this country have resulted in the development of powder for various field guns and howitzers, which, in night firings show only a small dark-red muzzle glow. Simultaneously with this development, efforts have been made to reduce the tendency of the nitrocellulose powders to absorb moisture, a property which they possess to a greater degree than double-base powders. This work has been so successful that the Ordnance Department is hopeful of being able to produce a flashless, non-hydroscopic, smokeless powder for practically all except larger calibers of guns, and even for the latter, the problem is not regarded as impossible.

Self-Propelled Track-Laying Artillery*

By

WILLIAM T. CARPENTER
Member A. O. A.

PART III. IDEAL AND PRACTICABLE TYPES

WHILE IT IS TRUE that today the self-propelled track-laying gun mount is in its infancy, and if we consider the short time, only three or four years at the most, covering its real development, as compared to the many years required to develop and perfect many of our great mechanical products of today, such as the modern locomotive, the electric traction car, or the latest types of war vessels, we must admit that perhaps its possibilities are not fully realized. Such being the case, there is some reason for the hesitation on the part of many in the past, as well as some few perhaps at present, to acknowledge that the horse-drawn vehicle has really passed out of modern warfare. The time honored affection of the soldier for the horse and the realization of the tremendous part that he has played in all wars of the past, was the greatest obstacle to the motorization of artillery—only partially accomplished in the late war. Of course, until the advent of the track-laying tractor, the horse had to be depended upon to take guns to positions on the field of battle where the wheeled tractor could not go. In commercial life we see "the handwriting on the wall" everywhere we turn, for in this country which boasts of over 9,000,000 motor vehicles, the horse will soon be entirely displaced as a draft animal. How much dependence should we place in this new type of gun vehicle? What limit should we set in our designs for the immediate future, and what then are the limits of size and speed to which it may be carried in its ultimate development?

Self-Propelled Mount for 75-mm. Gun or 105-mm. Howitzer Developed by Holt Mfg. Co. in Collaboration with Army Ordnance Department

The extraordinary progress of Ordnance design since the war is strikingly shown by the fact that, as late as 1919, the Line of the Army formally went on record as desiring a speed of at least 12 miles per hour in the *ideal* mount their fondest hopes pictured, whereas the mount pictured above climbing a 45-degree grade, has repeatedly attained a maximum speed of *30 miles per hour*, or two and a half times the original requirements.

Probable Forms of Attack and Artillery Weapons of Future

The tank, which may be considered as a mobile machine gun nest or a form of accompanying artillery, depending upon its armament, will lead the infantry attack of the next war. The infantry wave will struggle to keep pace with it—surely the infantry will utilize the mobility of the motor vehicle in some form whenever possible, and whether it does or not, the artillery must keep pace with and support both the infantry and tank if this wonderful life-saving weapon is to be utilized in the future as suggested by its results in the late war. The tank, however, in the future will meet with a resistance far more serious than in the last war and we may safely predict that wherever the tank appears it will at once encounter a well-organized and most serious anti-tank defense. It must then be armed with a cannon of greater size than heretofore or else it must be accompanied by an artillery vehicle so armed.

The artillery companion of the tank must be a self-propelled track-laying gun mount of the closed tank or partially closed type, bearing a light artillery weapon of the Divisional type for combating enemy tanks, machine gun nests, anti-tank and light artillery guns. It must go forward in line with the tank supporting it and attacking all weapons opposed to the advancing infantry wave. It may take cover where practicable, but it must combine its hitting power with its mobility to the extent of firing at the enemy targets stated above while moving at its maximum speed. This is the goal of the gun of the Divisional type, the "75," and perhaps that of the Corps at times. It matters not what designation or assignment we give these weapons, whether we call them Divisional, Corps, or Tank Artillery, Infantry Accompanying Guns or Batteries. Such a weapon will be required and the mission of the type will be close and continuous support of the front line—and once the advance is started it must keep clear of roads. Its movement must be continuous and characterized by energy, boldness and aggressiveness. At this time its fire must be direct and without any hope of observation—in fact, it must be in the hand-to-hand struggle.

This same principle of aggressive mobility should influence the designs of all types of heavy artillery, particularly those for seacoast defense. Mobility not only means utility in hitting the enemy but security as well—for frequent changes of position will be most essential in future warfare. Then again, in seacoast warfare a gun mount that will permit of a running fight, at close range, with an enemy at sea will be most desirable. In fact, it appears that the

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future artillery struggle will everywhere more nearly simulate naval warfare. It is for these reasons that we must harness the motor directly to the gun. The advantages of gun power, armor and speed in naval warfare are most suggestive in this respect and for coast defense work the ideal super type of gun mount would be one capable of sufficient gun power and mobility to meet and successfully oppose in a running fight the super types of naval wareraft. In other words, there is no limit in my mind at which we should stop in our attempts at self-propelled track-laying artillery design. This type of artillery should keep pace with naval power, and to do this, self-propelled carriages of the track-laying, or some better type, must be provided to mount coast defense guns of all essential sizes. I see no mechanical reason why we should not have super types for the primary armament, such as the 16-inch guns and howitzers, with all-round fire and stability enough for firing when in motion.

The question naturally arises as to where and how we may use this new type of artillery, particularly the super types.

In the future as in the past, our harbor and coast defenses will remain strong points in our line of national defense, protecting our naval bases, harbors, important cities and railway terminals. For reasons of economy, readiness, and perhaps for the "deterrent effect," it will be necessary to maintain a safe nucleus of fixed armament of the most powerful types, but perhaps more economically emplaced than in the past. These must be accompanied by the requisite amounts of anti-aircraft artillery, mines, torpedo defenses, searchlights, aircraft, etc. These fixed defenses must be augmented, of course, by a sufficient reserve of mobile artillery of both railway and self-propelled track-laying types, capable of swift mobilization to such points as are threatened by attack.

Special attention must be given to the protection of the intervening coast line susceptible to landing operations as well as to the land frontiers. The location of this mobile artillery reserve in peace times will depend largely upon its mobility and radius of action, upon the nature of the coast lines to be defended, railway and highway systems affording access to the coast lines. Possibly three or four reserve centers will suffice for each of our three coast lines and then again inland centers must be provided for, with a view to the protection of our land frontiers.

In future land warfare on a large scale, these weapons will play the same part as did the heavy artillery of many types in the late war, though to a much greater degree. It is hardly probable that we will ever use such weapons in a land war within our boundaries until after a possible defeat or isolation of our fleet, in which event we might have to repel an invasion by way of either of our land frontiers. The defeat of our fleet might occur in either of the following ways:

(1) By a superior fleet of one or more nations in a grand action.

(2) By a surprise attack without diplomatic indication when the fleet might be caught unawares.

(3) By an equal or inferior naval power by progressive methods, made possible by a division of the fleet—when parts of it might be attacked and defeated in turn in one or more of the oceans.

Our surest and most economical defense will always depend upon the maintenance of a grand fleet in each ocean which will be the equal or superior of any possible adversary in those respective waters, with their respective bases amply protected by coast defenses in all essential forms. The strategy of any state of naval preparedness, short of this, demands that the entire fleet be kept intact at all times as one ready fighting mass.

There will always remain the possibility for our use of these weapons overseas in Europe or elsewhere, in the event of another world war.

Those weapons mounted on railway carriages will for some time to come enjoy a mobile superiority in some localities, over the ideal super track-laying types here suggested, due to the fact that present railway construction will permit of their use in many localities out of reach of the super cross-country type, which would be too heavy for our present highway bridges and too large for narrow mountain roads with their intricate turns. But in this respect the railway mount is at a disadvantage as compared to the other mount, for on account of the expensive and exacting requirements of railway construction and the immense mileage that would be required to provide adequate defensive trackage, the operations of this type will necessarily be limited to the vicinity of the existing railway lines of the country, which are built entirely to satisfy the demands of our peace-time development. It is highly improbable that the country would during times of peace, stand the expense of any great amount of defensive railway lines—after the beginning of war it would be too late. It will not be a serious problem, however, to construct short railway extensions to the permanent coast defenses now located near important harbors and cities to provide these fortified localities with some defensive trackage. On the other hand, the track-laying type as a cross-country weapon, and which can easily travel on the sea beach, may be depended upon to cover practically the whole of our great coast line with much less preparation. It is hardly necessary in this connection to dwell upon the well known visibility and vulnerability of railway lines, or to cite the fact that the super-railway guns require the installation of turn-tables or curved firing tracks in order to obtain wide fields of fire. The track-laying type of vehicle has the advantage here; and again, if desired, it may move away promptly from its position once it is under enemy fire.

Characteristics of Ideal Artillery Weapons

The late war has definitely established the same struggle for mechanical supremacy in land warfare as has existed in naval warfare since the days of the wooden ship. In the development of artillery to meet this condition, the hands of the engineer should not be tied by any ideas of weight limits heretofore required for horse teams and military bridges of the past. The horse, it is true, set the pace in the warfare of the past, but we are now on the threshold of the horseless age. The transportation ideas of the world must adjust themselves to the mechanical means of locomotion now available. Carrying vehicles, roads and bridges must expand to satisfy the power and adaptability of the gas motor—the master of heavy loads. Weight, therefore, must not be the controlling feature of artillery design. The governing specifications must be gun power, mobility, speed, stability, endurance, armor for protection of the personnel and vital machinery; all in proper proportion to meet the missions of the particular types of weapons—with weight and dimensions accordingly.

The following characteristics are suggested as governing principles to be met in the design of ideal types of artillery weapons for the future:

Caliber and range of gun to suit the mission of the type.

All-round and high-angle fire.

Carriage to afford interchangeability of guns of same or approximately equal muzzle energy.

Self-propelled and cross-country vehicle with low unit ground pressure, such as the track-laying type.

(a) Non-delay in overcoming various ground conditions.

(b) Spanning ability to cross trenches.

(c) Shape and power to overcome the obstructions of the battlefield.

Capable of traveling through water to height of driver.

Stability sufficient to permit of all-round fire while in motion.

Short recoil—similar to naval guns.

Speed in proportion to the mission of the type—

(a) The equal of all other fighting and supply vehicles of land warfare.

(b) Seacoast defense types of sufficient speed to maintain a running fight with naval craft of similar armament within the defensive zone of the vehicle.

Unlimited cruising radius from standpoint of structural strength and repairs.

Turning radius to permit of a complete turn within the length of the vehicle.

Sufficient armor to protect power plant against light artillery weapons and complete armor protection for the personnel of front-line weapons against such weapons as will be encountered in the front line.

Machine gun defense for heavy types and anti-aircraft and machine gun defense of super types.

Motor and drive system:

(a) Ample power and strength, and of flexible type to give speeds suitable for the various conditions of terrain.

(b) Not affected by climate or weather conditions.

(c) Multiple power plant for larger types.

(d) Simple in design for readiness of production and repairs.

(e) Waterproof air cooled, noiseless and non-visible exhaust.

(f) Engine of general fuel type, *i. e.*, gasoline, kerosene, and other explosive fuel or gases.

Weight and overall dimensions sufficient to give the ideal fighting characteristics named above.

Types of Self-Propelled Track-Laying Artillery for the Immediate Future

Until such a time as an adequate highway system is provided, as suggested later, it will be necessary or advisable to limit the construction of the super types and those for the greater guns of the Secondary Armament to the limiting outlines of the International Clearance Diagram. This will enable this proposed type of artillery to use railway lines while en route to the reserve centers and to points of activity. The railways will thus serve, not only as a means of economical transport for long hauls, but also as a convenient means of passing the critical points of our terrain, which, for the present, may be overcome by such heavy loads along railway lines only.

This situation will probably prohibit the installation upon chain-treads of any gun greater than the 14-inch rifle, which for purposes of railway transport could be equipped with railway trucks, or perhaps it would be possible to design a type of truck roller for the chain-treads which could be used as railway wheels for the vehicle after removal of the chain-treads.

Such a carriage could be constructed to give the desired elevations to the gun and the same traverse of the top carriage as permitted by the present railway types.

The smaller types, for the Divisional, Corps and Army Artillery, may as a rule be built for loading on standard railway flat cars with overall loading dimensions within the limits of the Clearance Diagram.

The following types are suggested as practical solutions of the "ideal type" problem for the immediate future.

Light Field Artillery—The Divisional Types

The ideal may at this time be approached and perhaps realized in the design of the lighter artillery weapons such as the Divisional and Corps types. This is clearly demonstrated by the results obtained with Tanks in the late war, some of which weighed as much as 28 and 34 tons.

The ideal 75-mm. gun must have a pedestal mount with variable recoil and equilibrator giving all-round fire, elevations from —15 to +80 degrees, stability for firing in all positions of azimuth when in motion, a cross-country speed of from 5 to 12 miles per hour and a maximum road speed

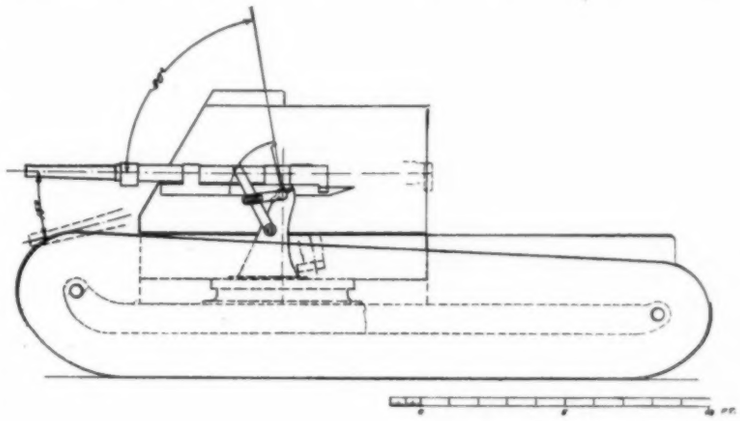


Fig. 21. Ideal and Practicable Type Mount for Divisional and Corps Guns

of not less than 25 miles per hour. The vehicle must be armored and of the closed turret type or nearly closed. Thickness of the armor will eventually be required for protection against a like weapon, but for the present, front armor affording protection against the 6-pounder may be sufficient with side armor of about 1 inch thickness. The length of the vehicle must be sufficient to give considerable spanning ability for crossing trenches. This will require a length of probably 20 to 25 feet overall. The width and height of the vehicle must be within the limits of the International Clearance Diagram to permit of shipping by railway.

A crew of 4 men, including the driver, should be provided for, and also space for a considerable supply of ammunition. The driver should be located in the turret with an all-round view. It is thought that such a gun vehicle can be constructed within a maximum weight limit of 25,000 to 30,000 pounds, in which case the gas motor should be of approximately 150 H. P. In appearance, the type suggested would resemble Figure 21.

The mount for the Divisional howitzer must be of the same general design throughout, with possibly the omission of the armor for the personnel, since the missions of this type are usually fulfilled by high angle fire and it will not be required in the front line action. The length and weight, perhaps, could be reduced, since its advance will be more leisurely, though the importance of stability for firing when in motion and the interchangeability of gun and howitzer must not be lost sight of.

Medium Field Artillery—The Corps Types

The vehicles for the Corps types should be constructed along the same lines as their divisional counterparts with possibly the omission of the turret, in which case the mount would appear as suggested by Figure 22, showing the 4.7-inch Gun on a carriage of the track-laying type. The increased power of these weapons will call for increased stability and this may be obtained only with a considerable increase in weight. In view of past experiences, it is predicted that these carriages could be built within weight limits of 40,000 to 50,000 pounds. The overall dimensions will

easily permit of loading aboard railway flat cars. It is thought that the speed limits should be the same as the divisional types. This would require a gas motor of 200 to 250 horsepower.

Heavy Field Artillery—Secondary Coast Defense Armament

The result obtained with the Marks I, II and III, for the 8-inch howitzer, 155-mm. gun and the 240-mm. howitzer, respectively, indicate that a satisfactory field carriage may be constructed for these calibers within weight limits of 80,000 to 100,000 pounds. The ideal form for this carriage from a mechanical standpoint would be of the platform type with pedestal mount as indicated by Figure 23, with a total width of from 12 to 15 feet, depending upon the gun, and a maximum carriage length of 30 feet. These dimensions would of course mean a radical change in highway and bridge construction as suggested later.

For the present, some such forms as shown in Figures 24 and 25 are suggested as practical solution for these calibers. In both cases the gun platforms are much lower. The ground clearance should be at least 18 inches. A top carriage of the pedestal or barbette type with short and variable recoil and equilibrator would then afford all-round fire and the elevations desired. A weapon of this type could most likely be constructed within the limits of the railway clearance diagram when loaded aboard the standard flat car. In case some calibers of this class should exceed these limits, it would be best to provide railway trucks for substitution when movements along railway lines would be necessary or desirable. This alternative would be better than unshipping the gun or top carriage in such cases. It does not appear unlikely that an adjustable railway track wheel system could be incorporated in the mount for ready application to the rails.

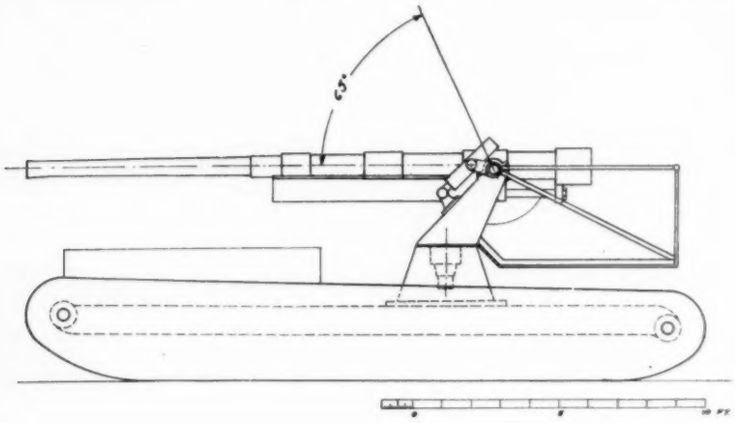


Fig. 22. Alternative Type for Corps Guns

In either of the types suggested by the illustrations Figures 23 and 25, both track-laying trucks should be so pivoted as to permit of complete revolution of each, in order to facilitate steering and to turn them crosswise when desired to obtain greater stability in firing. This arrangement will require a central gear drive and dual gas-motor power plants. The power plants for such a type would require a total of 400 to 500 horsepower in order to give a cross-country speed of 8 miles per hour and a road speed of 15 to 20, which would be most desirable.

Weapons of Greater Power—Secondary Coast Defense Armament

As we advance in size and hitting power to to meet the demand for types of special mission, we must adhere to the same ideal principles. This again means increased size and weight of carriage for such weapons as the 8-inch gun, Model of 1920, and the proposed 9.5-inch howitzer, as well as for the greater calibers of the Secondary Coast Defense types, such as the 10-inch rifle. The drop frame carriage seems to be the most practicable type and the illustration, Figure 25, is an attempt to show the new 8-inch rifle as it would appear on such a carriage. In the illustration, a set of treads are shown under the gun platform. They would be necessary to take the firing load and would facilitate the crossing of ridges and uneven ground. These treads would be "idlers" and not power driven in the gas motor type.

This carriage would be about 50 feet in length and in order to obtain all-round fire a width of about 15 to 20

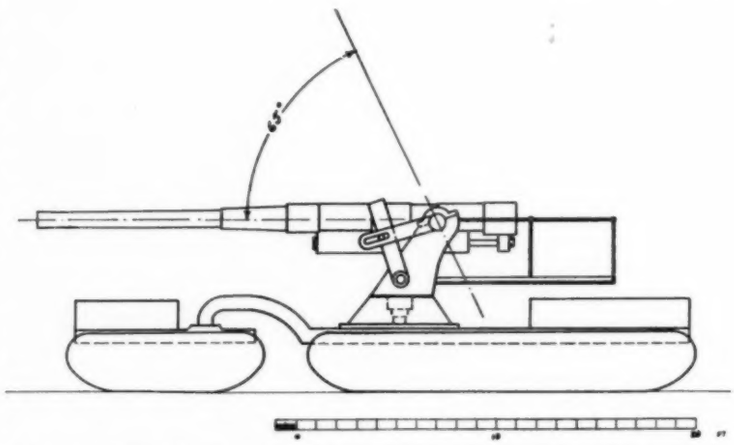


Fig. 24. Alternative Type for Heavy Field Artillery—Secondary Coast Defense Armament

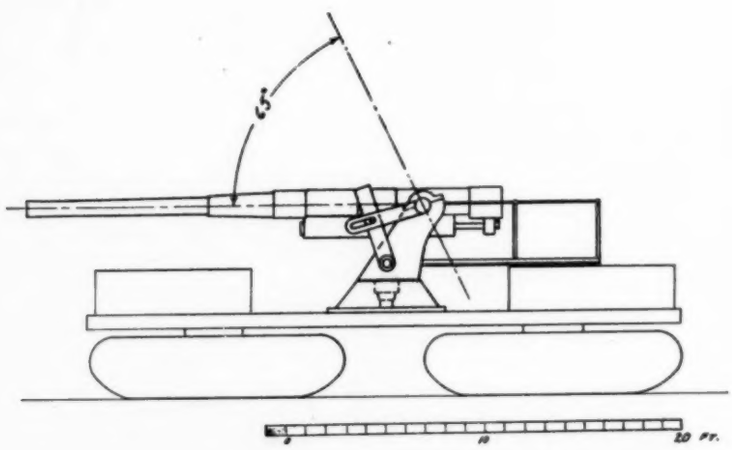


Fig. 23. Ideal Mount for Heavy Field Artillery—Secondary Coast Defense Armament

feet would probably be required. For the present, a carriage of the same shape and length could be constructed within the limits of the railway clearance diagram, which would permit of firing at angles of from 10 to 20 degrees either side of the center. Railway trucks could be substituted for railway transport. The total weight of such vehicle for the 8-Inch Rifle would probably not exceed 200,000 or 250,000 pounds, in which case a power plant system of approximately 800 aggregate horsepower would be required to give an essential cross-country speed of 5 miles per hour and a road speed of 10 to 15 miles per hour.

Super Types—Primary Coast Defense Armament

The ideal vehicle for this type must eventually have all-round fire, particularly when used for seacoast defense, where its missions in firing at moving vessels at long range will be most conveniently and effectively fulfilled when the mount is stationary and after a careful location and orientation of the gun. Traversing of the gun by movement of the treads will introduce changes of the center of revolution and level of the piece. The resulting errors in firing will be more or less serious depending upon the system of fire control, the nature of the carriage and the skill of the operators. The corrections for these resultant conditions will require time and if the carriages are so light as to require the installation of outriggers, the time element will be prohibitive.

The type of carriage shown in Figure 25 would readily satisfy the requirements for the 12-Inch Mortar and possibly the 16-inch Howitzer with weights in proportion.

For the other types, such as the 12, 14 and 16-inch rifles, the ideal super type of carriage would probably be as indicated by Figure 26, which shows the 14-Inch Rifle, Model 1920, on a vehicle of the track-laying type. Such a mount with all-round fire would weigh approximately 500,000 pounds and would be 100 feet long, 20 to 25 feet wide and about 20 feet high. The illustration is intended to show the trucks pivoted and to turn all-round. With such an arrangement, the driving power would be transmitted through the truck centers to a differential axle. The gas-electric drive, after it has been satisfactorily developed for this service, could be used to particular advantage in this case. In this event it would be better to provide one driving motor for each pair of treads, 4 in all, with power transmitted to a differential driving axle. The remarks made in regard to the idle treads for supporting the gun platform, Figure 25, apply in this case, except that with a gas-electric drive, these treads might be driven to advantage. Steering would be accomplished in much the same way as in the long ladder trucks now used by fire departments of our cities. The trucks, if turned cross-wise to the chassis, would increase the stability when firing in that position. A dual power-plant system, aggregating about 2,500 horsepower, would be required to give a cross country speed of 5 miles and a road speed of 15 miles per hour.

It is believed practicable to construct a carriage at this time similar to the above in appearance as indicated in dotted lines in the illustration and within the railway clearance diagram. A traverse of 5 to 10 degrees either side of the center could be obtained. Railway trucks would be required for transportation along railway lines.

Companion Vehicles

Each of the types suggested would require companion vehicles of the track-laying type for the service of ammunition and supplies, as well as others for maintenance. The coast defense armament would also require similar vehicles for searchlights with their power plants. The speed of such vehicles should be the same as their respective gun vehicles and the size and tonnage of ammunition carriers should vary with the size and weights of the projectiles hauled in order to meet the ammunition expenditure rates of the different types. In the design of these companion vehicles every effort should be made to standardize parts and to provide for interchangeability of parts with the corresponding gun vehicles. In this way the "spare parts" problem could be reduced to the minimum.

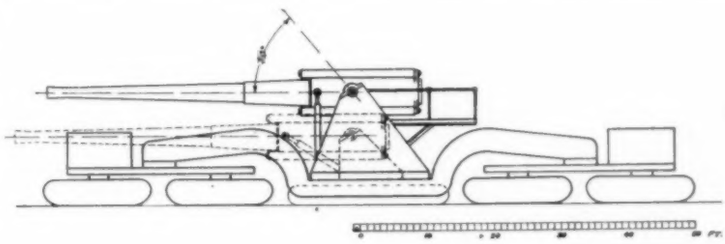


Fig. 26. Ideal and Practicable Super Types—Primary Coast Defense Armament

Fire Control

If we provide artillery of a roving nature, such as the self-propelled track-laying type proposed herein, or any other form of mobile heavy artillery for the defense of the unfortified stretches of our coast line that are subject to attack from the sea, it will be necessary in war time, at least, to provide a system of fire control to satisfy the needs of each of these sectors which in some cases will include a considerable length of shore line. The factors of economy and simplicity demand that any system or systems of fire control which may be adopted and depended upon for the service of the armament of the fixed defenses should be readily adaptable to heavy mobile guns in general and one, therefore, which may be easily extended in war time from the permanent coast defenses to these intervening localities, provided, of course, that the surveys of the coast lines, the determination of and marking of sites for fire control stations and other preliminary preparations were made in advance.

While our methods of fire control must be changed or improved so as to meet the requirements of long range fire, we will undoubtedly need, on shore, long horizontal base lines for position finding by some sight or sound method depending upon the accurate solution of the triangle. A chain or network of base lines and fire control stations will then be required along the entire length of each defensive zone of the seacoast to be defended by mobile heavy artillery.

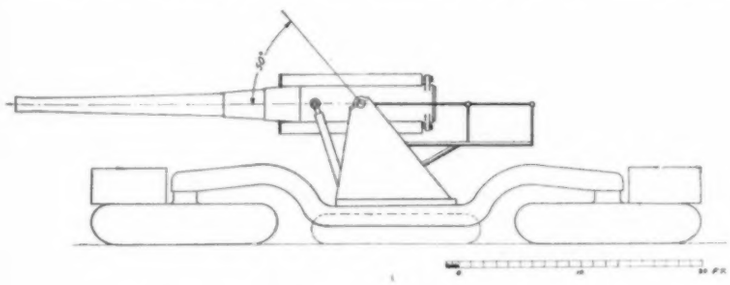


Fig. 25. Ideal Mount for Weapons of greater power—Secondary and Primary Coast Defense Armament

Propellant Charges

By

CHAS. S. REED

Member A. O. A.

"CHARGE, Propellant," is the term applied to a smokeless powder charge to distinguish it from the explosive charges in the projectile or in the booster. The purpose of the propellant charge is to drive the projectile from the cannon with sufficient velocity to reach the target. In fixed ammunition such as is used in the 37 mm., 75 mm. and 4.7-inch gun the propellant charge is contained inside the cartridge case and so becomes a part of the fixed complete round as issued. In larger cannon the complete round is so heavy that the propellant charge is issued separately from the projectile. The propellant powder is then put up in a silk cartridge bag and placed in an air-tight cartridge storage case. This type of ammunition is known as separate-loading ammunition, and is used in all our cannon 6 inches or greater in caliber. In 10-inch guns and larger, the charge is divided into equal sections to facilitate handling, and the propellant charge for one complete round is contained in two or more cartridge storage cases. A third and intermediate type of ammunition, known as semi-fixed ammunition, is sometimes used in medium caliber cannon. In this case the propellant powder is contained in a cartridge case which is not assembled to the projectile but is issued loaded and sealed with the powder inside. This type of ammunition is now prescribed only for the 105 mm. howitzer—the other cannon which used it all being obsolete.

If the only requirement of a propellant charge were to drive the projectile from the cannon with a certain prescribed velocity, the problem of propellants would be a very simple one—the velocity being obtained merely by increasing the weight of propellant powder to that required. Unfortunately there are other requirements which place definite limits on the kind and amount of powder which can be used. In order to keep the weight of the cannon down to the minimum the powder chamber is made as small as possible. This places a limit on the amount of powder which can be used. Similarly the strength of the gun around the chamber and bore is kept to the minimum in order also to decrease the weight of the gun. This places a limit on the maximum pressure which the powder may attain while starting the projectile out and the chase pressures it can exert while the projectile is in the bore. Furthermore the length of the bore of the gun is made short both from a weight and maneuvering standpoint and this places a limit on the time which the propellant powder has to force the projectile up to its required velocity, and finally the powder must all burn up before the projectile reaches the end of the bore.

It is one of the problems of the Ammunition Division, Ordnance Department, to meet the requirement for velocity without exceeding the limiting pressure, and using the chamber capacity and bore length given. In addition it must obtain a good degree of uniformity of action as regards the velocity attained and the pressure exerted. As a still further requirement it is necessary if possible to use propellant powder already on hand rather than develop a new powder for each new cannon.

In the most recent designs of cannon, this problem has been reversed. Given the velocity required of a certain caliber and weight of projectile and the permissible length of the bore, the Ammunition Division now designs the powder chamber as regards inside dimensions and decides the maximum pressure to be reached in it. This puts it up to the gun designer to build around this chamber and bore a gun having the necessary strength. This method of attacking the problem is the logical one and has already proved its value. In addition to the guarantee that the ballistic requirements can be met, co-operation is obtained between the Ammunition Division and the Artillery Division to the extent that the ammunition and the gun are developed at the same time and one is ready when the other is.

Figure 1 shows a diagram of the limits which a powder must not exceed. The curves show the pressure exerted by the powder on the projectile as it moves out of the gun. The dotted line A shows what happens if the powder burns too fast. The pressure rises quickly to the maximum and then, the powder having all burned up, the pressure drops off according to the curve PV=constant. The dotted line B shows what happened when the powder burns too slowly. The pressure rises so slowly that it does not have a chance to build up to the maximum allowed before the projectile has gotten a good start and thereafter the volume behind it is so increased as to make the attainment of higher pressure impossible. As the area beneath the curve represents the work done on the projectile it can readily be seen that the maximum velocity would be attained only with a powder whose pressure followed approximately the smooth curve C.

The approved type of propellant powder for cannon is a pure colloided nitrocellulose with the addition of a stabilizing element. The powder is made in cylindrical form with one or seven perforations as illustrated in Dr. Storm's article in this number. The speed of burning depends on the exposed surface so that by increasing the size of the grain the exposed surface per pound is decreased and thus the burning speed decreased.

The problem of finding a suitable powder then resolves itself into trying various sizes of grain until the proper one is found. Calculations will show the approximate size required but the actual test is required to definitely fix it. This firing of various size grains is the first firing done in a new gun. It is called the "granulation test" and is usually carried out in connection with the proof of the gun and carriage.

The maximum pressure exerted by the powder can be readily measured by inserting pressure gauges in the rear of the powder chamber. However, to date no satisfactory method of measuring pressures along the bore of a gun has been devised except for the very expensive one of actually drilling holes in the bore for the insertion of pressure gauges. It is, therefore, impracticable to determine the bore pressure curve for any given powder except by calculation, having given the maximum pressure actually obtained.

In order to always be on the safe side in conducting a

granulation test it is necessary to start with a powder expected to burn too fast, that is, one which will follow the line A, Figure 1, and not give dangerous bore pressures. Having established that this powder burns too fast to give the necessary velocity to the projectile, a slightly larger one is then tried, and so on. Finally, one known to be too large is fired to bracket the granulation required and definitely prove it to be correct. A curve such as shown in Fig. 2 is then drawn to indicate the correct size of powder for the

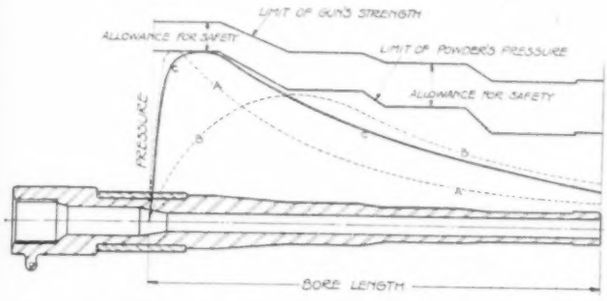


Fig. 1. Pressure of Propellant Powder and Its Limits

gun. In this figure the size of the powder is plotted against the velocity which it produces when the maximum pressure is reached. Point A being the maximum on the curve indicates the size of powder which will give the highest velocity in the gun. However, the velocity required is usually below this maximum. It appears that powder either of size B or C is just right for the gun and that any size between B and C can be used by reducing the weight of propellant charge to that required. This is not the case, however. It frequently occurs that powders of size C burn so slowly as to give pressures along the bore of the gun which are dangerous and actually bulge or burst the bore. The corect powder size is therefore indicated by the point B and, of course, a slight leeway toward point A is not especially to be avoided.

The curve shown in Fig. 2 is an ideal one. There are guns for which such a curve cannot be drawn. For example it is frequently impossible to obtain the maximum pressure when too large a powder size is used. The powder does not burn fast enough to build the pressure up to the maximum before the projectile has moved away and so increased the volume behind it as to make the attainment of any higher pressure impossible. The size of the chamber may be such that it is impossible to place in it enough powder of the larger sizes to reach the maximum pressure. In such a case points 3 and 4 may not be obtained and in the exteme case the requirement for velocity must be reduced in order to obtain a suitable powder.

It sometimes occurs that points 3 and 4 are the first ones obtained in the granulation test, and both are erroneously assumed to be below the maximum point of the curve, as suggested by the dotted line. Such an assumption might prove disastrous were it not for the fact that in such cases it is usually found impossible to extend the curve further on account of the chamber size being too small to permit the insertion of larger charges. This points out the necessity for starting the granulation test with a powder known to be too small and increasing the size by short steps to develop the true granulation curve. It also shows that at least three points must be known before any logical decision as to proper granulation can be made.

Along with the firings for the granulation test or right after them there are also introduced variations in the amount and location of the igniting powder. The primer in large cannon is too small to satisfactorily ignite the large powder grains. Its flash is therefore augmented by a charge of black powder, called the igniter, at least a portion of which is located at the rear of the propelling charge just in front of the primer vent hole in the breech block. It has been found that the location of the igniter has much greater effect upon the muzzle velocity and the pressure than does the quantity of the igniter. A number of tests have shown that by doubling the weight of igniter in any type of charge no change is effected in velocity or pressure. However, by placing the igniting powder in a core in the center of the charge as compared to placing it all at the rear, both the pressure and velocity are considerably reduced. Furthermore the uniformity of results when core ignition is used has been repeatedly demonstrated to be very much better than with any other type of igniter. Unfortunately this advantage of core ignition is only true of the single section charges. If the charge is divided into several sections and the core placed in each section the advantage in uniformity is lost and the pressure increased, the results in general being similar to those when the igniting powder is all concentrated at one point.

The first form of propellant charge used for nitrocellulose powder was somewhat similar to the multi-section charges now used. The bags were laced and the igniter was placed on each end of the charge so that either end could be inserted into the gun first. The larger charges were divided into sections and here again each section had an igniter on each end so that any one could be put in first. In 1913-14 it was discovered that by placing the igniting powder in the core a reduction in pressure could be obtained without a corresponding reduction in velocity. Also greater uniformity could be obtained with this type of charge. As a result single-section charges having core igniters were adopted for all guns using separate loading ammunition.

During the war a new type of propellant charge, known as the "base and increment" type, was developed for firing field shell. The purpose of this type was to make it possible to fire a reduced charge at three-fourths normal velocity. The full service charge was therefore issued in two sections: a base section containing powder for three-fourths velocity; and an increment section which by itself was of no

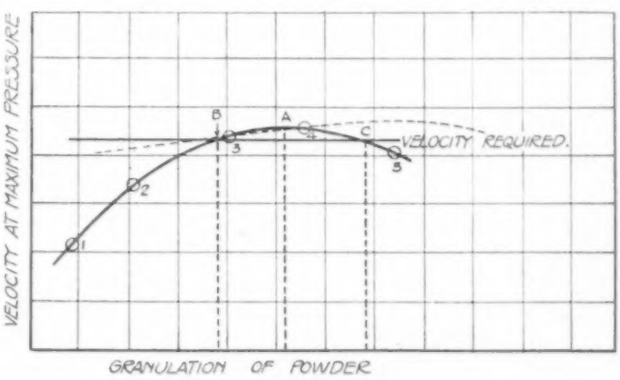


Fig. 2. Granulation Curve

value, but which with the base section would give the full velocity. Core ignition was at first authorized for this type of charge but investigation showed that for the medium calibered cannon if the igniter was placed at the rear of the base section only, satisfactory results could be obtained. The base and increment type therefore exists with the igniter in the base section only for the 155 mm. gun and 6-inch gun and with the igniter in the care of both base and increment sections for the 8, 10 and 12-inch guns. This type of propellant charge was issued for use only with high explosive shell. For armor-piercing shell and shot the

charge was still the single section core igniter type--for all guns 5 to 16 inches.

Propellant charges for howitzers were all provided with the igniter in the rear of the base section only. These charges all consisted of a base section to which several increment sections were tied. The inner zone velocities were reached by removing the sections in turn. Without the base section the increments were of no value, being of various weights and having no igniter.

The Coast Artillery in 1919 raised objections to the single section charge for guns of 10 inches and above on account of its excessive weight and flexibility causing difficulties in handling at the battery. It was necessary, for these larger guns, to revert to a multi-section charge similar to the type in vogue prior to 1913. Two tests were conducted at the Aberdeen Proving Grounds in the 12-inch gun, Model 1895, consisting of 60 rounds each, to determine the best type of igniter to use with multiple section charges. As a result the present type, as shown in the top view of Figure 3, having all the igniting powder contained in a separate pad at the end, was adopted (1920) for 10, 12 and 14-inch guns.

The propellant charge for the 12-inch mortar is different from any other charge. For this mortar it was necessary to establish a charge for a large number of zones of firing, the charge being a little larger for each successive zone until finally the full charge was used to give the outer zone velocity. The zones were originally selected so that a reasonable amount of overlapping existed between them, so that at any time the target would be well within one zone. This resulted in the 12-inch mortar charge being made up in a large number of ways. The charge for Zone 7, for example, was made to consist of one section which would give the velocity required for Zone 5. Placed on top of this and tied to it was an increment section which together with the Zone 5 charge would give the velocity for Zone 6. A second increment was then added so that the base section with the two increments would give the required velocity for Zone 7 (see Fig. 3). Similar charges for all the zones were made up but in no case did they consist of more than one base section with the two increments. There resulted considerable complexity in the issue and use of these charges as there were 10 or 11 zones to be reached. In order to avoid this the aliquot part mortar charge has been developed. This charge consists of 10 equal sections of powder with the

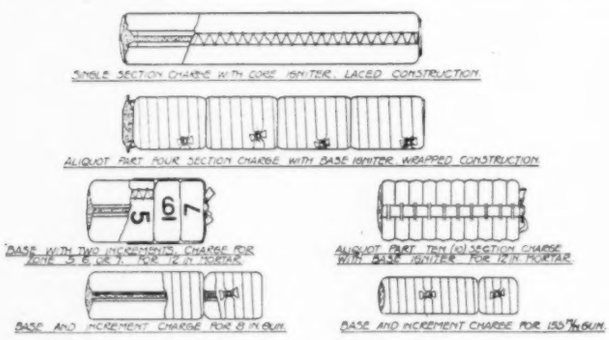

SINGLE SECTION CHARGE WITH CORE IGNITER, LACED CONSTRUCTION
ALIQUOT PART FOUR SECTION CHARGE WITH BASE IGNITER, WRAPPED CONSTRUCTION
5
6
7
BASE AND INCREMENT CHARGE FOR 8 IN GUN.
BASE AND INCREMENT CHARGE FOR 155 MM GUN.

Fig. 3. Various Types of Propellant Charges

igniter in the rear attached to the tying straps which go up over the 10 sections (see Fig. 3). With one such charge it is immediately possible to obtain velocities throughout all the required range by removing the required number of sections or tenths. It was also proved by tests that it was only necessary to establish the weight of charge for the outer zone for the 12-inch mortar and that fractional parts of this charge would give the same velocity as the same fractional parts of the charge for any other lot. The aliquot part charge for 12-inch mortar has not yet been adopted but this year all target practice is being held with this type and reports received so far are very favorable. Its early adoption is most likely.

The aliquot part charge has been adopted for the 8-inch Howitzer, Mark VIII½ and the 240 mm. Howitzer. The

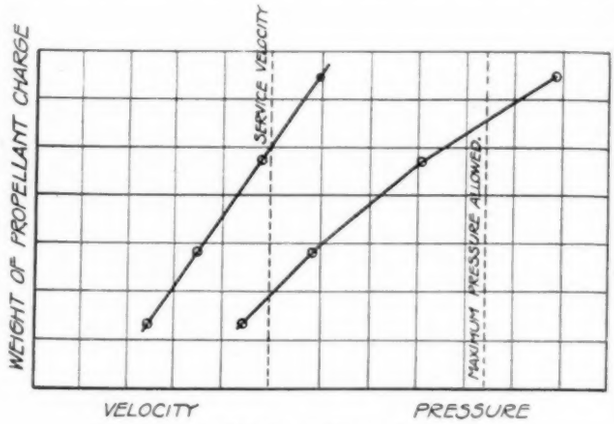


Fig. 4. Charge-Velocity and Charge-Pressure Curves

following table will serve to summarize the existing types of propellant charges:

A. *For Firing H. E. Shell*	
155 mm. and 6″ guns.	¾ Base and Increment, Igniter in rear.
8, 10 and 12 ″ guns.	¾ Base and Increment, Igniter in core.
155 mm. 8″ and 9.2″ Howitzer.	Base and Increments, Igniter in rear.
8″ How. Mk. VIII½ and 240 mm. How.	Aliquot Part, Igniter in rear.
B. *For Firing A. P. Shell and Shot.*	
6″ and 8″ guns.	Single section, core igniter.
10, 12, and 14″ guns.	Two section, aliquot part Igniter in rear.

Having determined the proper size of powder to use and the type and weight of igniter, the next step in the propellant problem is the determination of the correct weight of propellant charge for each lot of powder assigned to any particular type of gun. In the manufacture of smokeless powder it is necessary to divide the product up into lots. The size of lots is dependent only upon the capacity of the plant for blending the entire amount of powder in one lot as one mass. The largest lots used during the World War consisted of 150,000 lbs. each. A lot of powder, therefore, comes from the blender different from the preceding lot but the same throughout itself. This difference between lots requires that every lot be tested ballistically. The charge established for each lot must give the standard service velocity or at least the same velocity as all other lots. As a basis for comparison of lots and to insure that all charges are equivalent, a standard powder lot is selected and its charge for service velocity established by firings in one or more new guns. This charge once established has thus been proved to give service velocity in new guns and if ever fired afterward it must give the same velocity. Failing to do so the gun must be considered at fault or the measuring instruments in error.

One of the principal reasons for having the standard powder is that no two guns of the same caliber and model

will give the same mean velocity for the same charge when the same lot of powder is fired in them. Long series of firings of a standard powder have shown that from the very first, erosion in the gun causes the velocity on successive rounds to drop off. In the 14-inch gun, for example, the muzzle velocity of which is 2350 f.s., the loss in velocity due to erosion amounts, when the gun is new, to approximately 3 feet per second for every two rounds fired so that at the end of 40 rounds a charge which gave a velocity of 2350 f. s. when the gun was new, will only give 2290 f.s. After a certain amount of erosion has taken place its effect apparently becomes arrested and for a number of rounds, varying from 100 for the 14-inch gun to several thousand for the 75 mm. gun, there is no apparent change in the velocity of the standard powder due to the increasing age of the gun. The velocity in various guns of the same caliber and model therefore varies according to the number of rounds fired. There are certain other initial differences in new guns which cause also differences in the muzzle velocity obtained.

By firing a few rounds of the standard powder charge the extent of erosion in a gun can be checked and any difference in velocity from service can be applied to other results obtained the same day as a correction to normal conditions. In consequence of these corrections the new lot and the standard lot will give the same velocity when fired in the same gun. That this is the case has been repeatedly shown during the last year when it has been found desirable to check the charges established during the war in several of our largest seacoast guns. Those charges which had been established with the use of standard powder gave, in nearly every case, practically the same velocity as the standard powder did in the new test. It is one of the features of this method of firing that it eliminates instrumental errors of the day which have always been suspected but never definitely proved to exist.

The details of conducting a test to establish a powder charge, therefore, consist of firing a series of rounds with the standard powder to obtain the correction to normal velocity for the day. Then a few rounds are fired with the new lot of powder to establish the approximate charge required to give service velocity. These results are corrected by applying the correction for the day or a proportional amount of it according to the velocities obtained. Having established the approximate charge in this manner a uniformity series of 5 rounds is then fired. The correction is also applied to these rounds and all are plotted and the charge for service velocity selected graphically from the plot. A sample velocity-charge plot is shown on the left in Fig. 4. The curve on the right shows the pressure-charge curve which is also plotted to make sure that the pressure for the established charge is not above the prescribed pressure limit. Pressures, too, are corrected to normal by use of a pressure correction obtained in the same manner as the velocity correction.

Having established the corrected charge for a lot of powder nothing remains but to load the charges and issue them. All loading of propellants is now carried on at Picatinny Arsenal. In case of any doubt the completed charges are again tested before issue.

As a further step in assuring that all projectiles fired from a gun will receive the same initial velocity the issue of propellant charges is controlled by lot number from the Ordnance Office in the case of seacoast guns. Wherever possible but one lot of powder is assigned to any one battery. When not enough charges can be obtained from one lot then two lots are allowed, etc.

The Construction of a Range Table

By

F. L. CARMICHAEL

IN ORDER to construct a range table for a specified gun, projectile and muzzle velocity, it is necessary first to make so-called range firings at the Proving Ground where there are facilities for measuring the various elements which affect the ranges and deflections of the shots fired. A powder charge such as to give the projectile the desired muzzle velocity is established. Range and accuracy firings are then made at several different elevations from approximately the lowest to the highest permitted by the carriage. In case the range table is to be prepared for elevations from 0 to 45°, it is customary to fire groups of from 5 to 8 rounds each at five or more elevations between 5° and 45°, inclusive, primarily for range determinations. Groups of from 10 to 20 rounds each are fired at three or more elevations to obtain data on probable errors in range and deflection.

Practically all firings for the purpose of range table construction by the Ordnance Department are conducted at Aberdeen Proving Ground, Maryland. The Water Range is the principal range used for this work. As its name implies, the projectiles are fired into the water; and observations, that is, azimuth readings, are taken on the splashes in the water, by observers in conveniently located towers. To avoid the necessity of carrying out extensive computations to determine the range and deflection of each shot, a series of charts has been prepared showing with respect to an arbitrary set of rectangular axes, the coordinates of points in that part of the Chesapeake Bay into which the projectiles are fired. Lines are drawn on these charts representing azimuth lines from the different towers. Having the tower observations at hand, the position of the splash with respect to this arbitrary system is obtained by reading the coordinates of the intersection of the appropriate azimuth lines. It may be seen that accurate azimuth readings from two towers fix the position of the splash. In practice, for checking purposes, it is customary to have readings taken from as many as four towers. Knowing the coordinates of the gun and the splash, the range and deflection are readily computed. However, the observed ranges and deflections constitute only a small part of the data needed in the construction of the range table.

With regard to the measurements required to be taken at the gun, it is necessary to know the difference in levels of the gun and the splash, the jump of the gun, the muzzle velocity, the angle of elevation, the azimuth of the line of elevation and the weight of each projectile fired. Velocities are measured on five or more rounds during each day's firings. Vertical and lateral jump are measured by firing through card-board. In order to determine the actual angle of elevation, that is, the angle of inclination of the axis of the bore after the gun is laid for firing, it is necessary to correct the angle of elevation as read from the quadrant for quadrant calibration error and non-parallelism of the quadrant seat with respect to the axis of the bore. The angle of departure of the projectile from the

gun is determined when the jump and the angle of elevation are known.

While there are other methods by which the azimuth of the line of elevation may be found, perhaps the most frequently used method is that of bore-sighting on a fixed object down the range, at some convenient elevation different from that at which the shot is fired. By this means the direction of the axis of the bore at the angle of bore-sight is determined. Now, if the trunion axis is not horizontal, the gun will not rotate in a vertical plane. It is therefore necessary to make such measurements as will determine the inclination of the trunion axis in order that the change in the line of fire caused by elevating the gun from the bore-sighting angle to the firing angle may be computed.

Prior to the World War, the principal corrections for variations from standard atmospheric conditions were determined from surface conditions only. Unfortunately, however, conditions aloft are usually widely different from those at the ground. To meet the needs of modern warfare, it is necessary to obtain data on atmospheric conditions up to the maximum height attained by the projectile.

Data on wind aloft are determined by means of a rubber pilot balloon inflated with hydrogen gas. This balloon is released, and, at equal intervals of a minute, the horizontal or azimuth angles and the vertical or elevation angles of the balloon are measured by means of specially constructed transits, known as aircraft theodolites, located at two points at a distance of two miles or more apart. Having at hand the data thus obtained, the position of the balloon at the end of each minute is determined by triangulation. A so-called Flight Map is then prepared, showing, with respect to axes representing North-South and East-West directions, the projection of the balloon on the horizontal plane, and also its altitude at the end of each minute. The direction and the velocity of the wind at a given altitude is readily obtained from this map.

Temperature aloft is obtained by means of kites, kite balloons or airplanes. If kites or kite balloons are used, self-recording instruments known as meteorographs, record the temperatures at the various altitudes during ascent and descent. If an airplane is used, a meteorological observer accompanies the pilot and, by use of a thermometer and altimeter, records temperatures at conveniently chosen altitudes. Pressure aloft is determined from surface pressure. Humidity aloft, which is relatively unimportant, is estimated from surface humidity. Knowing temperature, pressure and humidity aloft, the density of the air is computed by use of the gas laws of Charles and Boyle.

Since a projectile spends more time in a given zone near the summit of the trajectory than in an equal zone nearer the ground, it is easy to see that effects produced by winds, for instance, in the direction of the line of fire in various altitude zones of equal depth, are not proportional to the magnitudes of these winds. It is therefore improper to assume that the average of the so-called range winds in all zones up to the summit of the trajectory is the ballistic range wind, that is, such a wind as, if blowing at all altitudes, would produce the same effect as the actual variable winds. On the contrary, the winds in the different zones must be weighted by the use of an appropriate weighting factor curve. Similarly, weighting factor curves must be used in the determination of ballistic cross wind, ballistic density and ballistic temperature. The procedure leading to the construction of a weighting factor curve requires the computation of a series of differential variations.

Firing records are prepared at the Proving Ground showing not only the observed ranges and deflections, but also the additional data required, as explained above, in the reductions to assumed standard conditions. Having such records at hand it is customary to apply approximate corrections, for the non-standard conditions existing at the time of the firing, to the mean observed ranges of the various groups and compute the ballistic co-efficients* corresponding to the adjusted ranges. A so-called C-curve is then drawn by plotting these values of the ballistic co-efficient against angle of departure and drawing a smooth curve through the points. Since no differential variations have been computed up to this point, the corrections applied to the observed ranges may be considerably in error. By the use of data contained in range tables for other projectiles of the same or slightly different calibers, however, it is usually possible to determine this preliminary C-curve with sufficient accuracy to permit the use of C's read therefrom as the basis for the trajectory and differential correction computations.

In the absence of suitable ballistic tables, it is necessary to compute trajectories and differential corrections for angles of departure at intervals of from 5° to 10°. These are computed for the standard muzzle velocity using values of C, corresponding to the angles of departure chosen, as read from the C-curve above described. The principal differential corrections required are those for range wind, cross wind and variations in muzzle velocity, density and temperature of the air, weight of projectile and angle of departure. Differential corrections for rotation of the earth are sometimes required.

The observed ranges are now corrected to the assumed standard conditions, making use of the trajectories and the differential corrections. Knowing the difference in levels of the gun and the splash, corrections for this item are obtained directly from the computed trajectories. Correction for jump is made by use of the differential correction for change in the angle of departure.

The ballistic co-efficients corresponding to the ranges thus obtained are computed. Since it is impossible to measure, with mathematical exactness, all the elements which affect the flight of the projectile, it frequently happens that there is not exact agreement between the C's obtained. Now, it is assumed that the ballistic co-efficient varies regularly with the angle of departure. In practice, therefore, the final C-curve is a smooth curve, usually without a reversal of curvature, drawn as nearly as possible through the mean of the final "C" points. This curve is of fundamental importance in the construction of the range table. With the exception of drift and probable errors, it forms the basis of all range table tabulations.

It is customary to include in the drift column effects due to both the gyroscopic action of the projectile, or drift proper, and the lateral jump of the gun. The observed deflections are therefore corrected only for cross wind, change in the line of fire due to elevating the gun from the bore-sighting angle to the firing angle when the trunnion axis is not horizontal and sometimes for rotation of the earth. Just as the final "C" points are not regular and a certain amount of smoothing has to be done, so it is with the final drift points.

Corrections for rotation of the earth are important only in the case of long range guns. For ranges less than 6 or 8 miles, both range and deflection effects may be disregarded altogether. For the 14-inch gun, however, firing a 1200-lb. shell with a muzzle velocity of 3000 f/s, which has a range at 40° elevation of approximately 25.6 miles, the maximum range and deflection effects at this elevation are 175 yards and 265 yards, respectively. The actual effects will vary, depending upon the azimuth of

*The ballistic coefficient, denoted by the symbol "C," equals w/id^2, where w, i and d are, respectively, the weight of the projectile in pounds, the coefficient of form of the projectile and the caliber in inches.

Continued on page 230

High Explosives

By

FRED OLSEN

WHEN a survey is made of the patents granted for compositions having explosive properties, it is evident that the general public has the impression that any substance, or combination of substances, which gives a loud report when struck a sharp blow, can be used either as a powerful tool by the construction engineer or as an agent of destruction in the arts of war.

Inasmuch as any comprehensive treatment of the subject of military high explosives would require more space than can be devoted to this article, and would involve an intensive chemical and physical treatment that would render the subject matter of interest only to the highly specialized explosives engineer and chemist, this article will be confined to a very general discussion of the present authorized military high explosives. It is particularly addressed to those whose main interests lie in other branches of Ordnance activities, and to the using services, the Line of the Army. The following explosives will be treated in this article: Mercury fulminate, Tetryl, TNT, Explosive "D." These explosives fall into three main classes, viz.: Initiators, e. g., mercury fulminate; boosters, e. g., Tetryl; bursting charges, e. g., TNT, explosive "D."

The relation of these explosives to one another is shown in Fig. 1. In the photograph of a sectioned 155 mm. shell, "A" is the fuze cavity into which the detonator, loaded with mercury fulminate fits. "B" is the booster explosive, tetryl; "C" is the bursting charge consisting of TNT.

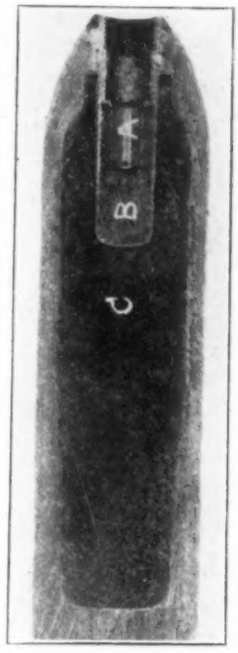


Fig. 1. Sectionalized 155-mm. Shell

The detonator is part of the fuze, which comprises, in general, a firing mechanism so designed that a spit of flame from a primer is delivered to the mercury fulminate of the detonator. The explosion of the mercury fulminate initiates the detonation of the tetryl in the surrounding booster. This in turn brings about the detonation of the TNT in the main body of the shell. It is seen, therefore, that there is actually a step-up system, not only with regard to the amounts involved in the successive portions of the train of explosives, but also with respect to the sensitiveness of these materials.

Thus a spit of flame causes the explosion of a small amount, viz., 30 grains, of a very sensitive and highly brisant material, mercury fulminate. This initiates a wave of detonation in a large amount, 450 grains, of the less sensitive tetryl. Finally the wave is transmitted to approximately 100,000 grains of relatively insensitive TNT.

The reasons for this arrangement of explosives are (1) Economy. TNT is the cheapest of the explosives named, being worth approximately 40c. a lb. as compared with 90c. for tetryl and $2.00 for mercury fulminate. (2) The mercury fulminate and tetryl are protected from shock by the mechanical design of the fuze and booster systems.

Although TNT is relatively insensitive, yet great care has to be exercised during the loading of the projectiles to prevent air pockets forming as the molten TNT solidifies. If these cavities are allowed to form, the entrapped air may be compressed to such an extent by the force of setback that sufficient heat is generated to raise the temperature of the material above its explosion point. This phenomenon of setback is due to the inertia of the explosive charge which does not immediately take on the acceleration given to the shell body by the pressure of the propellant gases. As a result of this a premature burst of the shell may occur either in front of the muzzle or even in the bore of the gun. This would result in the destruction of the gun and possible injury to the gun crew. However, even TNT is not sufficiently insentitive to shock to be a suitable explosive for filling armor-piercing shell. When, for example, a 12-inch shot is fired against caliber plate, comprising specially tough steel 12 inches in thickness, the mechanical force of the shock is enormous. The transformation into heat of the loss of kinetic energy of the projectile as it performs the mechanical work of rupturing the plate, estimated at approximately seventy to eighty million foot pounds, produces a blinding white flash, which gives the impression that the shell has detonated on impact. Explosion would actually result if the shell were filled with TNT, but when Explosive "D" (ammonium picrate) is used the explosive passes through this terrible ordeal unscathed. It is, however, caused to detonate completely at some point behind the plate by the action of the small amount of tetryl in the booster.

None of these explosives give any indication by their appearance of their destructive properties. Mercury fulminate has somewhat the appearance of dark gray sand. Tetryl looks like corn meal. TNT resembles a light brown sugar, while Explosive "D" occurs in crystals varying from yellowish orange to red in color, with an attractive palatable appearance, but with a taste as bitter as quinine.

Fig. 2 shows photo-micrographs of crystals of each of these four materials; mercury fulminate, tetryl, TNT and Explosive "D." The power of an explosive is mainly dependent upon two factors, its strength, and the velocity with which the detonating wave can traverse the explosive.

The strength may be measured by means of a ballistic mortar. Ten grams of the explosive are detonated in the chamber of a mortar, the necessary confinement being secured by a snugly fitting plug or projectile. The mortar is suspended from knife edges, and is so arranged that as the mortar is swung back by the force of the explosion, a marker is pushed along a calibrated arc measuring the amount of the swing in degrees. The test consists in determining how many grams of TNT are required to cause the pendulum to swing through an angle equal to that caused by the explosion of ten grams of the explosive under test. For Explosive "D" the TNT value is 10.5 grams; the TNT equivalent is for tetryl, 12.1 grams.

The velocity at which the detonating wave can traverse the explosive depends upon several factors, among which the most important are the density and the diameter of the core of the explosive being tested. In general it may be said that the denser the material is pressed and the larger the diameter of the core, the faster the wave of detonation will travel through the explosive.

For densities of approximately 1.45 and with an explosive

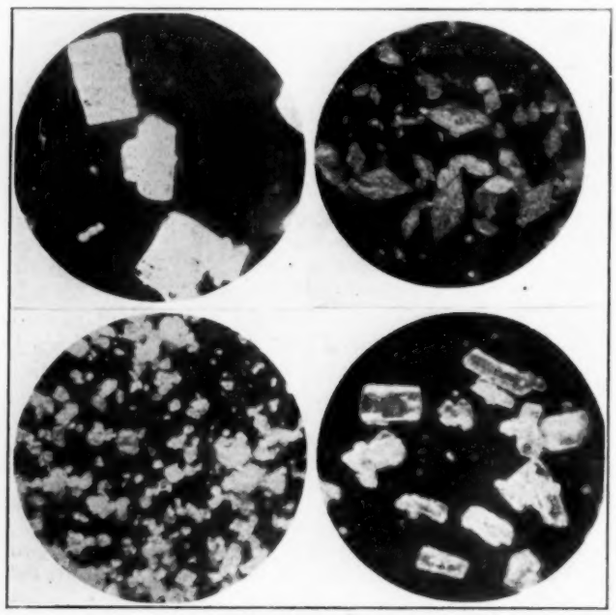


Fig. 2. Photo-Micrographs of Explosive Crystals

TNT (crystal) — Mercury Fulminate
Tetryl (crystal) — Ammonium Picrate

column 1¼-inch in diameter rates of detonation are about:

TNT	6,000 meters per sec.
Tetryl	7,000 meters per sec.
Explosive "D"	5,500 meters per sec.

Although figures serve to indicate to the explosives engineer the relative power of various explosives, the fact remains that the merits of an explosive are judged in the final analysis by the amount of work it can do. In the November-December 1921 issue of ARMY ORDNANCE, photographs were shown which served as evidence of the tremendous force exerted by "The Biggest Bomb in the World" in which 4,000 lbs. of TNT made a crater 65 feet in diameter and 19 feet in depth.

Mercury fulminate is tremendously destructive. Less than 5 lbs. of it unconfirmed recently detonated in a tile building. Three sides and the roof with all the interior fixtures were demolished, only one wall remained intact.

In the manufacture of these explosives there is only one ingredient common to all, viz., nitric acid. Since the main source of nitric acid is Chile saltpeter, it is imperative that in time of war the sea lanes to Chile be kept free from the menace of submarines, unless nitrogen fixation plants, such as exist at Muscle Shoals, are developed to such an extent that we are no longer dependent on foreign nitrate for the essentials of war.

In addition to nitric acid, mercury fulminate requires metallic mercury and grain alcohol. The manufacture is a relatively simple operation comprising dissolving mercury in nitric acid and pouring the solution into grain alcohol. Gray crystals of mercury fulminate settle out, which are removed and washed.

Tetryl on the other hand has the great disadvantage of involving a very tedious process of manufacture. Benzene must first be treated with nitric acid to form nitrobenzene or oil of mirbane. This is reduced by iron filings and hydrochloric acid to give aniline. The aniline is mixed with sulphuric acid, wood alcohol, and a little iodine to serve as a catalyst or lubricator. The whole is cooked in enamel-lined closed vessels under high pressure. This part of the manufacture is difficult and costly, as the highly corrosive liquid frequently renders the vessels unfit to withstand the temperature and pressure involved. The product is dimethylaniline, which finally on nitration with strong nitric and sulphuric acid mixtures yields trinitrophenylmethylnitramine, or tetryl, for short.

TNT or trinitrotoluene results from the nitrating action of mixed sulphuric and nitric acids on toluene. Toluene is obtained, together with a much larger amount of benzene, from the by-product coke ovens, although considerable quantities may also be secured in times of emergency from the manufacture of artificial gas, and also by a special breaking-up or "cracking" process applied to oils, preferably of an asphalt base.

Explosive "D" or ammonium picrate is made by treating picric acid with ammonia. The manufacture of picric acid involves the conversion of benzene to phenol and the nitration of this to trinitrophenol or picric acid.

It will be noted that next to nitric acid, the products of the coke oven, benzene and toluene, are of greatest importance. There are practically unlimited supplies of benzene available for military purposes, and problems relating to the more extended use of this material in explosives are being actively pursued at Picatinny Arsenal.

Research work on several new high explosives is under way at Picatinny Arsenal, and is already giving indications that very satisfactory results will be obtained. These investigations have in view the development of new explosives from one of the intermediate products in the Fixation of Nitrogen process at Muscle Shoals. These new explosives are derived from lime nitrogen which is one of the most valuable fertilizers and finds extensive use in several branches of agriculture. Thus by the proper development of the Muscle Shoals plants we have one of the best means of fulfilling the motto of ARMY ORDNANCE, "Effective Industrial Preparedness for War as Our Strongest Guarantee of Peace."

The Construction of a Range Table

(Continued from page 228)

the line of fire and the latitude at which the gun is fired. There is current among the British a report to the effect that their defeat near the Falkland Islands was due to the fact that the effect of the rotation of the earth on deflection is different in the southern hemisphere than in the northern. No allowance was made for this difference.

As an example of the magnitude of the effects due to variations from standard conditions, data applicable to the gun and ammunition referred to in the preceding paragraph are tabulated below for an angle of elevation of 45°, the range for this elevation being about 26.5 miles.

Increase in range due to—

An increase in muzzle velocity of 30 f/s__ 750 yds.
A decrease in air density of 10 per cent____2635 "
A wind along the line of fire of 25 mi/hr__ 685 "

Since the variations from standard here assumed are not larger than those frequently met with in the field, it may be seen that projectiles fired without taking account of non-standard conditions may miss the target by 4,070 yards, or approximately 2.3 miles, even though the gun is correctly laid otherwise. The need for carefully constructed range tables and accurate data on atmospheric and other conditions which affect the flight of the projectile, is therefore apparent.

Military Pyrotechnics

By

S. WILEY

THE importance of pyrotechnic material from a military standpoint is not generally appreciated by the layman, as very little has been published on this particular subject. The World War has shown the great possibilities of this class of material, and has indicated the lines along which it must be developed. Practical development of pyrotechnics, therefore, is an important as well as an interesting problem of the Ammunition Division.

The army of the present day is equipped with many means of communication; radio, telephone, heliograph, semaphore, and panels are all used in an effort to meet the need for communication between the various units. In this connection the statement of a Colonel of Infantry is quoted: "The importance of pyrotechnics has not been appreciated. In France all other means of communication except by means of runners were interrupted. Quick response to the call from the Infantry can be obtained by pyrotechnics. Any other means may be wiped out when most needed. In France we never had sufficient pyrotechnics." It is readily seen that a dependable system of communication by pyrotechnics would be a very valuable addition to the liaison system.

Parachute Type of Signal with Smoke Charge Burning

Pyrotechnics have been employed for centuries. The compositions were used by the magicians and priests of earlier times. More lately they have been employed in signals and for purposes of general display. The use of the airplane gave another field for this class of material. By their means aircraft were enabled to communicate with one another and with the ground, as well as to receive information from ground troops. Moreover, by the use of these mixtures artificial illumination could be supplied when needed.

Signal rockets and the Very pistol with its cartridge, at times redesigned to meet current methods of production, have been used since Revolutionary times. The rockets have been handed down to the present day with very little change. The Very signal cartridge, as used by our army prior to the European war, consisted of a ten-gage shot-gun shell loaded with an illuminating or color pellet in place of the shot charge. The cartridges were fired from a breech loading pistol. When the United States entered the war a survey of the requirements of our army was made and the few pyrotechnics on hand were found to be obsolete. New and improved pyrotechnics, both for day and night use, were needed, because of the new tactics employed in trench warfare.

In order to produce the pyrotechnics required by our troops, a Pyrotechnic Section was created in the Trench Warfare Branch of the Engineering Division of the Ordnance Department. To this Section was assigned the work of designing, developing, and manufacturing experimental pyrotechnics. A laboratory was established at the American University, Washington, D. C., where samples of signals, smoke torches, and airplane flares were made and tested. The system developed by this section, a system adapted to the manufacturing facilities in the United States, was not used. The French system was adopted instead, because of the fact that our troops were so closely connected with the French, in many cases both being supplied from the same depots.

These signals were designed for immediate use, the nature of the pyrotechnic contents being such that the life of the signal or flare was not longer than three years. Only a very small part of the American-made pyrotechnics reached France prior to the Armistice, and very few were used on the front. The signals, rockets, and flares used by the United States troops were of French manufacture except for the wing-tip flares and smoke torches which were purchased from the British.

These pyrotechnics proved to be very inefficient in performance. Many failures in functioning were encountered, the malfunctioning being mostly due to too light construction. This was especially true of the rockets and paper encased flares. They did not stand up under the storage conditions which existed in the advance ammunition dumps.

After the Armistice was signed, a thorough investigation of the functioning and effectiveness of the signals and flares used by our troops was made. A board of officers from the different interested branches of the service was appointed to make recommendations for a system of pyrotechnics to be adopted by the army. After considering the available information, the Board was of the opinion that we had too many signals, that too many types caused confusion in actual combat, and that better results would be obtained by reducing the number and increasing the efficiency of the signals to be used. It was necessary to take

pyrotechnic material out of the class of fireworks and place it, as nearly as science and experience would permit, on an equal footing with other ammunition with regard to ruggedness of construction and dependability of operation.

After the Pyrotechnic Board had made their recommendations, the Ordinance Department established a pyrotechnic unit at Picatinny Arsenal. This unit has been carrying out the experimental work necessary in order that pyrotechnic material shall meet the demands made on it. The plant consists of an office and drafting room, a small but well-equipped machine shop, a number of mixing and charging

Above: Signal Rocket used during World War
Middle: Very Pistol and Cartridges for Signalling
Below: Newly developed Signal Cartridge

sheds with their machinery, the necessary small storehouses, and a photometric gallery. The section is complete in itself and carries on the whole of the development work, including the design. It is so equipped that on very short notice it can be made into a production unit.

As stated before in this article, pyrotechnics used during the war were unsatisfactory, both as to material from which they were constructed, and as to dependability. It may not appear to be a difficult problem to construct a cartridge that can be projected into the air and at the height of its trajectory produce a brilliant colored light, bright illumination, or a dense cloud of distinctive colored smoke. Although a signal cartridge has a very plain exterior, it is made up of a number of units, each of which has a definite task to perform in a definite short time. Malfunctioning in any one of these units means a failure of the signal as a whole. The problem is further complicated by the fact that, due to factors which cannot be controlled, the conditions under which ejection of the pyrotechnics occur vary widely. It is therefore apparent that a successful solution of the dependability problem is not an easy matter.

The new type of pyrotechnic signal has been built mainly with the idea of producing a signal which would be entirely dependable as to functioning and which could stand rough handling and would not deteriorate after storage under field conditions. The latest type produced has been tested only recently, and gave excellent performance. The question of dependability of operation has been satisfactorily answered. The signal as built is rugged and entirely waterproof; in fact, in the recent tests several cartridges were fired after they had been immersed in water for a considerable time. They all functioned perfectly.

At the same time endeavor has been made to use more suitable illuminating compositions. In the past almost all of the illuminating material used in the signals was made up according to the old standard fireworks mixtures. While some of these mixtures produced good illumination and color, they proved to be unstable in storage. In others the visibility was poor, due to the enormous volume of smoke given off, in some cases the smoke being sufficient to completely mask the illumination or color effect. This was especially true in the daytime if the direction of the wind was in the line of vision and toward the observer. The Pyrotechnic Division has to a great extent overcome this difficulty by using mixtures containing chemicals that will give very little smoke and at the same time increase the candle power. The following comparisons will serve to illustrate this point.

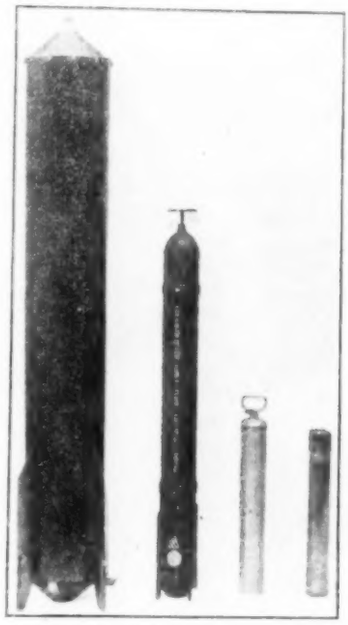
The white flare used by the Infantry during the war for illuminating "No Man's Land" was a single star cartridge. This was projected to an altitude of about 200 feet and burned approximately five seconds with an intensity of about 10,000 candle power. On account of the low elevation and low candle power, only a small area was illuminated. In the new signal that has been recently tested, the pyrotechnic elements consist of a number of illuminating pellets which are expelled from a cartridge projected to a height of approximately 500 feet and are dispersed so that they light up a much greater area. The total candle power developed is over 250,000, the time of burning being about five seconds. Again, the old type of V. B. cartridge containing the red star burned from twenty to twenty-five seconds with a low candle power; the color was not brilliant and it gave off a large volume of smoke. The red color light that has been recently developed, new chemicals being used in the mixture, produces a brilliant red color with very little smoke. It has a candle power twice as great as the red star V. B. cartridge.

The ground position lights produced during the war were used by the Infantry to signal the location of their lines to observing aircraft for transmission to the rear. The position lights were placed at intervals along the bottom of the trenches or in any location screened from the enemy. These lights were made in three colors—red, white and green. The pyrotechnic composition was charged into a cylindrical paper case which was provided with a crude self-contained friction igniter device. These position lights were too fragile to remain effective under service conditions; they were not waterproof, and, since the composition used to produce the red color was very hygroscopic, the red position light was not stable in storage. A new type of position light is under consideration and it is the aim of the Pyrotechnic Unit, by using recently developed color mixtures, to produce a compact, waterproof, serviceable light having greater visibility than the old type of position light.

The airplane flare used by our forces during the war was an exact duplicate of the Michelin flare of French manufacture. This flare gave at best only 70 per cent performance. It is dropped from a releasing device suspended below the plane and falls from 200 to 400 feet before the flare and parachute are expelled from the flare case. It burns from four to seven minutes with an intensity somewhat more than 300,000 candle power. Under average weather conditions, when dropped from an altitude of 2,000 feet, it will burn out just before reaching the ground. This flare does not have a variable time fuze and functions at approximately the same distance below the plane every time.

The recommendations of the Pyrotechnic Board require that two types of airplane flares shell be developed; one having a candle power of about 400,000 and a burning time of seven to eight minutes; the other having a candle power of about 800,000 and a burning time of four minutes. Both of these flares are to include a time fuze to permit the functioning of the flare at any selected distance below the plane or to allow the flare to be dropped inert.

A statement of the points which must be considered in solving these problems will be of interest. The weight of illuminant required to give this candle power and time of burning is approximately thirty pounds. A parachute must be selected large enough in size to sustain this weight of composition at an effective altitude during the entire time of burning. Since it is possible that the flare may be required to drop twenty odd seconds before expulsion, it will be necessary to provide a parachute strong enough to withstand the strains which occur when the parachute snaps open. The various components must be sure of operation. They must be combined into a whole which is convenient to handle. The finished flare must be absolutely waterproof, entirely safe in storage ,and inert until it is released from the plane. These points will serve to indicate the many details which must be worked out before a successful solution is arrived at.



Left: New million candle-power flare 6 ft. in length
Left center: Michelin 300,000 c. p. flare used during War
Right center: New 250,000 c. p. flare
Right: Small (60,000 c. p.) French flare used during War

The wing-tip flares previously referred to are small flares burning for one minute and giving 10,000 to 13,000 candle power. They are used to enable the aviator to make a forced landing at night or on a field that is not illuminated. The pyrotechnic composition is charged into a cylindrical paper case. These flares are held in light metal holders attached to the underside and at the extreme end of the lower wings of the plane. Wires run from the flares to a switch in the cockpit to provide for ignition of the flare. Only about 60 per cent of these flares function under service conditions, the failures being due to the fact that the containers were not waterproofed. New wing-tip flares must be designed to do away with the objectionable features of the present type. An improved flare holder will greatly remedy the defects.

Besides the work on actual signals, the Pyrotechnic Division has had to consider means of projecting them. The rocket has had to be abandoned on account of its bulky form. Other means had to be devised to propel the signal to the altiture required by considerations of visibility. Several methods have been employed and these are shortly to be demonstrated for the approval of the line branches of the service. In addition an entirely new projector has been devised for the use of the Air Service. Considerations of safety of the operating personnel governed its development, and it may be said that the new projector, in addition to being absolutely safe, is, at the same time, simple and positive in action, and easily installed on any type of machine. It will do away entirely with the many troubles which were encountered in the use of the Very pistols, lately declared obsolete.

In this article the pyrotechnic situation has been described in a general way. The different problems are closely related to one another and encouraging progress is being made on them. A great mass of details are still to be worked out, but a big start has been made toward making pyrotechnic signals really dependable ammunition.

The Commercial Utilization of Smokeless Powder

In connection with the fact that many millions of pounds of smokeless powder manfactured during the World War and now in excess of the amount required for current target practice and as a war reserve, have been declared salvage by the United States and European governments, it is of interest to consider the uses to which such war materials can be applied in commercial industries.

The base of all military smokeless powders is nitrocellulose, the product resulting from the treatment of cellulose (cotton or purified wood pulp) with a mixture of nitric and sulphuric acids. The smokeless powder of the United States, and much of that used by England and France during the war, is practically pure nitrocellulose, gelatinized by means of a suitable solvent, which is practically eliminated during the drying process. The Cordite used in England and the Ballistite of Italy contain nitroglycerin in addition to nitrocellulose.

The commercial utilization of smokeless powder is therefore a possibility in any of the industries which employ nitrocellulose, and the latter is an important factor in many products. Celluloid and simliar products, sold under various trade names, are composed mainly of nitrocellulose; most kinds of artificial leather are made by coating cloth with solutions of nitrocellulose; many lacquers and varnishes are solutions of the same product. Successful application of nitrocellulose smokeless powder in the manufacture of artificial leather is being made in this country by merely crushing or grinding the powder, treating it with a suitable "mixed acid" in order to partially de-nitrate it, and then dissolving it in a suitable solvent. This treatment increases the viscosity of the resulting solution, so that the proper film can be obtained without an excessive amount of solvent. Recently 35,000,000 lbs. of surplus Cordite were purchased from the British Government for use in the manufacture of artificial leather in this country. In the case of nitroglycerin powders such as Cordite it is, of course, first necessary to eliminate the nitroglycerin before the nitrocellulose can be used for such purposes. Such procedure is not necessary with nitrocellulose powders.

Apart from the many possible uses of smokeless powder in the manufacture of artificial leather, lacquers, and the pyroxylins such as celluloid, its explosive properties give it a natural application in the manufacture of blasting explosives, while its nitrogen content (12 to 13 per cent) indicates the possibility of its application as a fertilizer material.

The manufacture of a detonating explosive, similar to dynamite in its action, is carried out, according to U. S. Patent 1,382,287 of June 21, 1921, by grinding nitrocellulose smokeless powders to a suitable degree of fineness. U. S. Patent 1,376,030 of Apr. 26, 1921, covers the manufacture of a mixture of ground nitrocellulose smokeless powder with a nitrostarch explosive to form a blasting powder. There are many possibilities of manufacturing cheap and efficient blasting explosives from ground smokeless powder mixed with suitable oxidizing materials such as nitrates, etc.

In order for the nitrogen of smokeless powder to be available for fertilizer purposes, it must be converted into a soluble nitrate, nitrocellulose being an organic nitrate insoluble in water. Experiments conducted by the United States Department of Agriculture have shown that the nitrogen is most readily made available by decomposing the powder with sulphuric acid, distilling off the resulting nitric acid and absorbing the vapors in alkalies, thereby directly producing soluble nitrates, in which form the nitrogen is available as plant food.

With the many possibilities of utilizing smokeless powder for industrial purposes, there is no doubt that the vast stores of munitions which have been released and are still being salvaged, will be diverted to profitable and beneficial uses.

Picatinny Arsenal

By

F. H. MILES JR.

Member A. O. A.

LET'S all begin to think in terms of complete rounds of ammunition. Thought is father to the deed. Guns require complete rounds of ammunition. These rounds must be thought of as units. Every component of the complete round is important but most important is the assembly, the complete round. It must function and also be capable of manufacture in large quantities.

The tendency always has been to develop officers as fuze men, projectile men, explosive men, rather than as ammunition men, and the fact that the development has taken place at separate establishments has practically precluded the consideration of the complete round, except in a cursory manner, by the Ordnance Officer or the Ordnance Board at the Proving Grounds. Further, a very important function—the loading or filling of fuzes, projectiles, etc.—has never received the emphasis and study which co-ordination of the complete round necessitates.

Those of us who know what difficulties existed during the late war in getting simple parts, such as adapters and boosters, to assemble mechanically, to say nothing of the loading function involved, will realize the absolute necessity for co-ordination in the larger, immeasurably more intricate unit, the complete round.

Imagine the complete round development by the fuze man, projectile man, case man, explosive man, and loading man, all working under one roof and you have the central idea of Picatinny Arsenal.

Modern ammunition manufacture runs the gamut of the chemical and metallurgical industries. It has its dangerous phases. The manufacture of explosives and the loading operations are dangerous. The development arsenal therefore has to be of such location that the dangerous operations can be performed with safety to the surrounding communities. Picatinny Arsenal has such a location. The Government Reservation now known as "Picatinny Arsenal" lies in the hills of northern New Jersey in the Middle Forge Valley, Morris County, and is half way between the Hudson and Delaware Rivers. The Reservation takes its name from Picatinny Peak, a mountain which rises abrutly from the general level of the valley, and at the foot of which lies a beautiful lake about a mile long. The name, like many others in the neighborhood, is of Indian origin.

The country about the Arsenal is rough and mountainous and for that reason is sparsely inhabited. It is quite probable that the presence of iron ore in great abundance, the forests, ready to be converted into charcoal, and the numerous waterfalls for furnishing power to operate forges, drew the settlers to this part of the country. The presence of the ore was known to the Indians before white men arrived and their name for the locality "Succassunna" meaning "Black Stone" or "Heavy Stone," has been applied to the plains which extend westward from the hills in which the iron ore was first found.

In 1749, Jonathan Osborne purchased the falls midway between Denmark and Mt. Pleasant and built what became known as "Middle Forge." This forge was located at the south end of Piccatinny Lake and a water wheel operating a trip hammer was the principal forging tool. Parts of the equipment of the forge are preserved at the Arsenal. The forge was continued in use until a few years before the United States purchased the land on which it stood.

The wild, rough nature of the country is what caused it to be chosen as a site for a Government Depot. The need of such a depot where powder and explosives might be stored in large quantities and where powder mills might be erected was seriously felt, both during and after the Civil War. A Board of Officers, therefore, was convened in New York City in 1866 to consider the question of establishing two depots and to recommend suitable locations.

In July, 1879, Major F. H. Parker, Ordnance Department, was assigned to the duty of inspecting tracts of land in the neighborhoods recommended by the Board, with a view to purchase by the United States. After closely examining the various sites, it was decided that the location near Dover, N. J., met with all the requirements and in 1880 the tract known as Middle Forge became the property of the United States.

On September 6, 1880, the Secretary of War directed the Reservation to be known as the "Dover Powder Depot." Major Parker remonstrated in the following letter:

Office of the Atlantic Powder Depot,*
New York City, Sept. 9, 1880.

The Chief of Ordnance, U. S. A.
Washington, D. C.

Sir:

I have the honor to acknowledge receipt this day of Special Orders No. 189, Headquarters of the Army, dated Sept. 6, 1880.

I respectfully call attention of the Department to these objections to the name "Dover Powder Depot," by which the new post has been designated in the order, viz.:

The site is not in the town of Dover but in Rockaway.

The name is too suggestive of a well known medicine.

In the future, when the quarters and office are built on the site the nearest post office will be at Mount Hope or Port Oram.

There is nothing in the name to indicate that it is a U. S. establishment.

I therefore recommend that the name be U. S. Powder Depot, or if it is thought necessary to have it localized, I suggest that Mount Hope or Rockaway (after the township and river) or Green Pond, or Picatinny (the name of a mountain peak on the tract) or Cliffwood, or Middle Forge, or Denmark are better than Dover Powder Depot.

F. H. PARKER,
Major of Ordnance, Commanding.

Four days later, a special order was issued directing it to be designated as the "Picatinny Powder Depot". In June, 1883, it became known as the U. S. Powder Depot, which name was used until October, 1907, when it was designated as Picatinny Arsenal.

The first building, the erection of which was started in 1880, was a magazine two hundred feet by fifty feet with a six foot basement. It was designed to hold 10,000 barrels of black powder, the only kind of powder then in use.

*Note: It is to be noted that the name of the depot prior to September 6th, 1880, was the Atlantic Powder Depot, while it was still on paper.

The foundation of this building was of stone quarried at the Arsenal. The magazine was completed in 1881 and is still in good condition. Five such magazines and several auxiliary buildings, including an office, fire house and stable, were subsequently built.

About the year 1900 the need of a storage place for armor-piereing projectiles and high explosives began to receive serious attention. Six projectile sheds were erected in 1902, and in the following year the installation of a plant for filling projectiles with Explosive "D" was begun. A temporary Maximite loading plant was operated for some time and several thousand armor-piereing projectiles of various calibers were filled. Explosive "D" soon replaced Maximite for bursting charges and in 1906 and 1907 the projectiles that had been filled with Maximite were unloaded.

In 1906, a water wheel and dynamo house (now used as Fire Headquarters) were erected on the site of the old forge, and also a shop building including machinery for the capping, grooving, tapping and banding of projectiles. A building in which to assemble fixed ammunition was also erected at this time but the work was afterward abandoned. The building was temporarily used as a chemical laboratory and later altered for the installation of a high explosives plant.

The Fortifications Bill approved June 25, 1906, contained an appropriation to provide for the erection of a powder factory, and, after inspecting several other sites, the Depot was found to be the most suitable. The work of erecting and equipping the powder factory was begun in April, 1907, but the actual manufacture of powder was not begun until January, 1908.

In 1911 the high explosives plant for the manufacture of picric acid and explosive "D" was installed in the building previously used as a chemical laboratory, and was successfully operated until it was closed in July, 1918.

The greatest credit is due the efforts of Gen. O. C. Horney during his tour as commanding officer of the Arsenal. Although greatly handicapped by lack of funds and the fact that practically a new industrial effort was being initiated, the Ordnance Department placed the Arsenal on a successful working basis as a powder manufacturing establishment and developed facilities for the surveillance, test and improvement of the manufacture of propellant powders. The high explosives work was started shortly afterward and the general chemical facilities of the Arsenal were initiated and greatly expanded.

The beginning of the World War found Picatinny Arsenal well grounded as an explosives manufacturing, testing and handling institution, including facilities for loading shell with explosive "D" and the filling of propellant cartridges for guns. Some of the installations, however, were becoming obsolete or inadequate and with our entry into the war the production facilities at Picatinny Arsenal were almost negligible in view of the total required, so that it was logical that Picatinny should become an experimental center where development work on explosives could be undertaken, that personnel for the explosives service should be trained there, and that its unused land should be used for the erection of storage buildings.

Picatinny Arsenal comprises 1,600 acres and some ninety-six hollow tile permanent magazines were constructed for storage purposes. Some sixty-five temporary buildings for storage and barracks for guards were also built. The hollow tile buildings are an asset to the Arsenal but the temporary buildings will all eventually be torn down or remodelled permanently. Some twelve miles of railroad connecting the new storage areas with the main Arsenal were built and will be of permanent advantage. Aside from the storage construction and railroads, and the construction of some fifteen temporary research laboratory buildings, very little construction was done during the war and almost no attempt was made to increase or remodel existing manufacturing facilities. The explosives manufacturing plants were finally shut down and all emphasis was placed upon experimental and developmental work. This called for the extension of the testing ground facilities where excellent work was done during the war in ballistic and fragmentation work.

It may be well to bring out at this point a real contribution to the effective prosecution of the war made by Picatinny Arsenal in the field of explosives. It was the training which had been given to a number of officers who had been educated at Picatinny Arsenal and who held the reins during the war on explosive supply in its broad sense. Had Picatinny made no other contribution, their services were worth many times over all that had ever been spent on Picatiny Arsenal as an explosives center. Certain explosives interests will doubtless agree to this now although they earlier deprecated the establishment of Picatinny Arsenal as an explosives center. More misunderstandings arose between contractors and government representatives during the war, due to misinformation on the part of the latter, than from any other cause. Fortunately, the explosives industry did not have to deal with explosives representatives who did not appreciate the necessity for cooperation and while the necessary supervision was given to the industry, production was possible as evidenced by the stupendous quantities of powder and explosives which were produced. This was true of all Ordnance functions in which adequate officer personnel had been developed along the specific line concerned. Ignorance breeds suspicion. The establishment of educational and developmental facilities within the Department reverts eventually to the benefit of all prospective producers of munitions.

Another point should be brought out here and that is that a broad policy of cooperation with those industries which become extremely necessary in time of war will depend upon the education of Ordnance Officers to a realization of the stupendous task involved and the necessity for intelligent mutual understanding as the only means of making war-time production possible. Failure to educate Ordnance officers leads to their failure to perceive the necessity. Hence, the necessity for development centers like Picatinny Arsenal.

It is not believed that the world as a whole realizes how much the co-operation of American powder industries with the American Army and Navy prior to the World War has meant. I think it is no exaggeration to say that England and France could not have continued in the war had it not been for American-made powders and explosives. The nucleus of powder men trained prior to the war made possible this gigantic effort, and Picatinny did its share.

If this achievement of Picatinny Arsenal came about because Picatinny was the development center for powders and explosives before the war, how much more valuable should Picatinny's future contributions be as the development center for the complete round of artillery ammunition. We should also remember that if the American production of complete rounds of artillery ammunition had been necessary to win the war in November, 1918, Germany would have been victorious.

It is to be hoped that those who have charge of production for any future war will be willing to produce in smaller units. American peace-time production calls for doing things in a large way. We sometimes forget that each of these industries had to begin in a small way. The ammunition plants for future wars should begin in a small

way as does any new industrial effort. Let them grow if they will, but start in a small way. Some production is better than none. What you do today you can double tomorrow because you have done it once today, instead of half-doing it twice.

The lessons of the war logically came up for discussion immediately after the armistice, and one of them was artillery ammunition. It was apparent that we must get at the root of our troubles, and analysis led inevitably to the fundamental principle of thinking in terms of the complete round of ammunition as distinguished from thinking of the fuze, projectile, or powder separately. Muddling through has its advantages, but the disadvantages far outweigh them. Co-ordination requires thought, and co-ordination of artillery ammunition requires the co-ordinated thoughts of the development men for its component parts. Bring these men together and you have it.

Where to place this co-ordinated development work was a problem especially when it came to facing post-war economies. An attempt was made to secure Edgewood Arsenal because of the basic facilities such as power and housing there, and on account of its proximity to the Aberdeen Proving Ground. This was not practicable because of the needs of the chemical warfare service. An attempt was made to secure sufficient funds from Congress to build near Aberdeen Proving Ground a development center. This could not be done in view of the necessity for retrenchment. So it was decided that Picatinny Arsenal offered the best alternative. It was realized that Picatinny could not be ideal, but so much in the way of fundamentals was already established that it offered the best possibilities for the least expenditure of funds.

Having decided on Picatinny Arsenal as the place to concentrate on, plans were laid to install development facilities which were not already there by collecting from the various war plants the necessary equipment so far as possible.

Plants were built or remodeled using as far as practicable existing storage buildings in lieu of new construction, and between 1919 and 1921 the following facilities have been established or amplified.

1. A Metal Components area consisting of a tool room, a fuze shop, three projectile machining shops, a cartridge storage case and container shop with plating facilities, and a fuze-loading development laboratory. Plans for this area include the installation of a separate experimental shop (this work now being done in the tool room), and the gradual installation of forging, drawing and heat-treating equipment.

2. A High Explosives area in which buildings adaptable to experimental manufacture have been built and a considerable amount of experimental high explosives equipment gathered. The buildings include a control laboratory, a raw materials manufacturing building, a raw materials storage building, two nitrating houses, a purification house, a graining house, a dry house, a packing house.

3. Propellant Manufacturing area (powder factory). A control laboratory has been equipped in factory. The boiling tub house and beater house have been replaced and modernized, and changes are being undertaken which will ultimately give modern installations for first stage powder and drying. Excellent powder is being produced on a very small scale.

4. A Loading area, consisting of a bag manufacturing and loading plant, a melt loading plant, a new Explosive "D" press plant, a booster loading plant, a black powder primer loading plant, a fuze loading plant including facilities for handling, storing and drying mercury fulminate, a "complete rounds" assembly plant, and the necessary service magazines, heating plants, etc. Plans for this area include the addition of a small conditioning installation for work on time fuzes, delay elements, etc., and the building of a small bomb loading unit, separate from the present melt plant.

5. Pyrotechnic area, consisting of a mechanical laboratory, office and testing building, five storage buildings, and two manufacturing lines, one for nitrates and another for chlorates consisting of four small buildings each. This is probably the best equipped unit of its kind in existence. This area also handles experimental grenades and trench warfare materials.

6. A Testing area consisting of three ranges, one for detonating work, a second for cannon velocity and pressure work, and a very complete small arms testing range; a sectioning plant, fragmentation chambers, a ballistic mortar, a ballistic pendulum, flame testing apparatus, rate of detonation instruments including a Mettagang Recorder, a photographic laboratory, and a calorimetric bomb installation, etc.

7. An Ammunition School with the fixed purpose of emphasizing the relation of the components to the complete round has been started at the Arsenal. Officers and qualified civilians will take the course. All officers assigned to duty at the Arsenal will be required to take the course.

8. Services of various kinds have been amplified, including alteration of the power house, a new electrical transmission system, a new steam transmission system heating the entire Arsenal, amplification of the water system, and the installation of a sewer system and a sewage disposal plant.

There has been a consistent effort to build up the officer personnel at the Arsenal and to gather an efficient civilian personnel who shall be experts in their particular lines, and progress is being made in this direction.

To the end that the personnel may be satisfied, the living and working conditions should be enhanced in every way possible. In developmental work the penny-wise-pound-foolish methods must be abandoned. Extravagance is not urged, in fact it is economy which is being urged. Where tens of dollars may be spent in proper developmental work, millions may be wasted if developmental work is not intelligent and of the highest order. The country has no right to place the responsibility for such development unless it makes such development possible. Incidentally, such development work is bound to find some application in the peaceful arts and industries, or the past is no criterion of the future. Scientific research results are almost always fundamental, therefore, universal.

At the present time the Arsenal consists of 258 permanent buildings of which approximately one-half are buildings for manufacturing or experimental work. Development work is proceeding in all of the departments of the Arsenal and much of its development work has been successful. Conspicuous among the development work was the flashless powder recently tested at the Aberdeen meeting of the Army Ordnance Association, and the loading work on the fuzes and bombs used successfully against the battleships ex-*Alabama* and *Ostfriesland*. Pyrotechnic development is reaching a very satisfactory stage. Other developments are in work, some of which cannot be cited for obvious reasons. On the whole the experimental outlook is very promising.

A start has been made, therefore, in collecting all the various functions for the development of artillery ammunition under one roof, and although it will take years to equip properly, adherence to the central principle will assure its triumph and mean much in American blood in any future conflict. Let's *think in terms of the complete round* of artillery ammunition.

New 105 mm. Howitzer Carriage. Rock Island Arsenal has recently completed a new type of 105 mm. howitzer carriage, which has been shipped to the Aberdeen Proving Ground where it will be put under test soon. The 75 mm. gun is commonly recognized as the backbone of the artillery, but the experience of the World War emphasizes the fact that this gun must be supplemented by a howitzer of equal mobility. The Germans used large numbers of 105 mm. howitzers, and this caliber has been taken as most suitable for pairing with the 75 mm. gun. The Ordnance Department has also put under test at the Proving Ground a howitzer of this size on a carriage of the split-trail type, and one mounted on a vehicle of the caterpillar type. The carriage just completed is of the so-called box trail construction which does not permit a wide traverse, but this limitation is offset by a decrease in weight and increased simplicity of construction. The howitzers being tested are more powerful than those used during the World War.

Long Range Small Arms Firing

PART VI

Vertical Firing

By

GLENN P. WILHELM

Member A. O. A.

THE WORLD WAR created new and more difficult ballistic problems than the wildest imaginings of the pseudo-scientific writers had ever pictured. Of these problems, probably the most difficult is the necessity of firing effectively against aerial targets, since anti-aircraft fire deals with three dimensions instead of two which were all it had been necessary to consider in previous conflicts.

There are few of us who, in our youth, did not possess some form of a .22 caliber rifle and who, in one of the numerous forays which such ownership often led to, did not at one time or another fire straight up into the air in order to hear the bullet come down. The success of such futile efforts was about as pronounced as those of other experimenters who have essayed the same stunt. There is a fascination about firing skyward which goes with the ownership of small caliber rifles and the speculations among all shooters as to what happens to the bullets which go up but never seem to come down are as universal as the use of guns.

Fig. 1. Browning Machine Gun Firing Vertically at Daytona Beach, Fla., for the purpose of determining the characteristics of vertical fire, including the time of flight

History of Vertical Rifle Fire

As far back as Benjamin Robins (about the time of our French and Indian War), such experiments were held, and it is significant that Robins, while one of the first to record his test, was at least successful. However, Robins used a smooth bore and, according to his own figures, his ball only rose to the moderate height of a half mile, the vertical time of flight being about 30 seconds. This may account for his success in spite of the inaccuracy of his implement, the musket. The fact is worthy of note that one of the most careful and painstaking small arms experimenters in this country, the late Dr. Franklin W. Mann, failed to obtain any results when he turned his attention to vertical firing. Dr. Mann had the same curious desire as the rest of us, so he selected a perfectly calm day and fired the Krag bullet upward from over a small pond which measured somewhat less than a quarter of a mile in extent. In spite of more than usual care being exercised, Dr. Mann never heard from any of his bullets again either in the pond or in the woods which surrounded the pond.

Major Hardcastle (British), by means of firings carried on at the River Stour in England during September, 1909, determined the vertical time of flight of the British Mark VI bullet as about 52 to 57 seconds and the Mark VII as about 48 to 51 seconds, these figures having already been obtained by calculations with ballistic tables. Another British small arms expert, Mr. Tippins, during some firings which he carried on at the same river, determined that for rifle bullets some fell base first, others on their sides, while still others fell point first, there being a certain critical angle within which the falling bullet might return either way. Later on Mr. Tippins repeated the experiment with the Maxim machine gun and, according to the published accounts, the bullets returned in regular sequence, the individual time for the bullets of the burst being from 50 to 60 seconds, the average being somewhere around 55 seconds. These tests were held in 1910.

Published figures for the German Spitzer bullet give the height of the vertical flight as 9,000 feet with a total time of flight of 57 seconds, 19 of which are spent by the bullet in ascent. In explaining the critical angle, the writer states that when the bullet falls at a distance exceeding 1,000 feet from the gun the bullet usually falls point first. British figures for their Mark VII bullet are generally given showing the height of ascent as about 9,000 feet with a total time of flight of 55 seconds of which 19 is the time up.

Other figures published at various times in England and other countries have shown that anti-aircraft guns of about 2 inches caliber and 2,500 feet per second muzzle velocity, throw their projectiles about six miles high with a time of ascent of about 40 seconds and a descent of about 54 seconds. The figures for the .22 caliber rifle are usually given as: height, 3,000 feet; time of ascent, 10 seconds; time of descent base first, 24 seconds. All of these figures are from publications as to the vertical flight of small arms bullets.

Official Tests in the United States

In the United States the first tests held on a very large scale by an organization of expert personnel and with the proper facilities, were those of the Small Arms Ballistic Station in Florida during the fall of 1919 and spring of 1920. The former were held over water and a full account of the tests is given in the Report on Vertical Time of Flight for Small Arms Ammunition, extracts from which will be quoted in the remainder of this article. The latter firings were held over sand at Daytona Beach, where it was possible to recover the bullets themselves.

The object of the vertical fire tests in Florida was to determine the vertical time of flight of Small Arms Ammunition for purposes of comparison, and to obtain certain data regarding the laws of air resistance to small arms projectiles of various weights, shapes and velocities.

For the Miami tests, an observation tower was selected so located that under normal conditions it was surrounded on all sides by shallow water extending several hundred yards. This water was almost invariably calm. The tower was fitted up with head cover as it was the intention to bring the falling shots down on to the tower itself in order to facilitate observation.

The heavy Browning Machine Gun was used in the first two tests. This gun was installed by bolting the legs of the Cygnet Tripod to a heavy wooden frame with the forward legs of the tripod nearly horizontal, and the barrel pointing vertically. When the Mann steel "V" Rest was substituted for the machine gun in some tests, the same tripod arrangement was used, the "V" Rest being substituted for the gun and fitted to the tripod by the lugs formed on the bottom of the steel trough for that purpose. The "V" then of course ran vertically instead of nearly horizontally, as in normal firing.

Inclination of the machine gun, or of the Mann barrel, from the vertical, necessary to correct for wind, drift or other error in the vertical flight of the bullet, was measured by means of the ordinary machine gun clinometer, applied to the panoramic sight bracket to measure the north or south inclination, and to the side of the receiver to measure east and west.

It was found in some tests, held with the Mann barrel and with various shoulder rifles, that accurate measurement of the barrel inclination could be obtained by merely placing the clinometer on the muzzle of the gun, changes being made, not by moving the gun with relation to the rest, but by moving the entire "V" block by means of the ordinary tripod adjustments. The necessity for accuracy in inclination measurements may be appreciated when it is noted that a change of 25 mils—less than one and a half degrees—moved the bullet entirely off the landscape so far as any observation from the tower was concerned.

Adjustment of the barrel of the Mann Rest was of course simple, it being merely laid in the "V" and held there by a gunner as it was fired. The various types of sporting and military rifles, however, offered another problem, with their varying external shapes of barrel, sight and stocks. Tests proved, however, that any of those tried could be laid in the "V" rest with entire accuracy from shot to shot, although of course it was necessary to hold the rifle in the vertical "V" during firing. There remained therefore only the necessity for measuring the barrel inclination, and the use of the clinometer on the muzzle proved that in the rifles tried out, at least, the muzzle was cut out at right angles to the bore, allowing accurate vertical alignment with a zero reading of the clinometer.

The arms fired in the tests consisted of the Browning Machine gun with various sorts of ammunition; the Mann barrel for our service cartridge; the French and Swiss service rifles; the .351 caliber Winchester self-loading rifle (sporting); the .35 caliber Remington autoloaded sporting rifle; a British Model, 1914, sub-caliber rifle arranged for the .22 caliber Long Rifle cartridge, and the .45 caliber service automatic pistol, Model, 1911. In all, eight different arms were used in the vertical firing tests. The ammunition fired included over fifteen different types.

Out of the five hundred or more bullets fired vertically with intent to cause them to strike the tower on return, but four struck the tower with its upper floor area of about 100 square feet, and one struck a boat moored to the tower. Two of these were recovered, both of them Model 1919, boat tailed, one landing in the boat and not bouncing out of it, the other landing in a pail of water used for cooling the Browning Machine gun. One of them made a shallow indentation in the edge of a thwart of the boat, conforming to the bullet traveling at an angle of about 45 degrees with the vertical, the other making an almost imperceptible dent in the bottom of the pail. The form of this dent indicated that the bullet had either not returned base first and bullet vertical, or else had turned sideways on the impact of its base with force sufficient to make a partial imprint of its length.

Two others struck the armor plate without leaving a mark, and a fifth, a service 150-grain bullet, struck the soft pine lower platform near the edge and bounced off into the water. The imprint, plainly showing the shape of the base of the bullet, was round, about the bullet diameter, and not more than 1/16th inch in depth. The returning velocity of the service bullet is evidently not much in excess of 300 f. s.

Bullet Spin

It is evident from the amount of splash made by the impact of the returning bullets, by the various sounds emitted from the falling bullets, and by the discrepancies in results, that all bullets do not retain their spin and return base first.

Other investigators have stated that the British service bullet and the German service bullet return base first but that there is a certain critical angle beyond which the bullets will return point first. Between these two extremes the bullets return partly sideways. It is probable that the majority of the bullets fired in these tests, except those already specifically mentioned, return base first, although in a great many cases there is undoubtedly considerable wobble.

Noise of Bullets

Although previous experimenters in vertical firing make no mention of having observed the fact, all bullets fired vertically and returning close to the firer, announced their coming at least a second before striking the water, by a very distinct and peculiar whirring whistle, not unlike the note of a cricket in some instances. With much wind blowing, such as in one test where 15 miles of wind prevailed, the noise becomes less noticeable, but under still conditions the noise of bullets returning 120 to 150 meters away was clearly audible. The noise of the returning Model 1919 bullet was alleged by some observers who had been under much artillery fire in France, to be very similar to the whistle of the high velocity enemy shell popularly known as "whiz-bangs."

The Swiss service bullet, which returned in the most uniform time of any fired vertically, had a very peculiar noise, difficult to describe but agreed upon by the observers as being a "chirp," not unlike that of some birds, a peculiar dry buzzing or chirping noise and not the mixture of whistle and whir that distinguished the other bullets. This bullet made much disturbance on entering the water, more so than the service bullets. The French service bullet made a very loud whirring, whistling noise, but had a soft quiet entrance into the water.

The first burst fired in these tests fell too far to the south to be plainly observed, and would have escaped notice, but the very noticeable noise drew the attention of the observer to their return 150 meters or more away. This burst was of 1906 service ammunition. All of the large caliber bullets, such as the .351, the .35 and the .45 pistol bullet, whirred very noticeably.

Wind Effect

When the wind was light, the dispersion of a burst was very small. Repeatedly a burst of ten shots was returned within a circle 24 meters in diameter. When, however, a bullet returned in time much less or much greater than the others, then it rarely fell with the main group, landing 75 meters away at times—possibly so far away in other instances that the bullet was never noted in its return. Under the conditions of one test with Mann barrel, where three shots were fired with ten seconds interval, repeatedly one bullet of the three returned close to the tower, but the other two were never noted. Evidently they encountered varying wind currents.

Analysis of the wind prevailing at the ground level, and the deflection put on the gun to bring the bullets close to the tower, reveals contradictions that seem to indicate that at one time the ground currents may indicate the general strength of the currents higher up, but another time the wind at the ground level is not the current that is moving the bullet. This is easily understood when it is remembered that the bullet is spending most of its time above the thousand foot mark, and that there are two seconds of its flight in which it moves upward 16 feet and back the same distance. The greatest deflection used was 110 mils (4° 40′) necessary with a 15-mile wind to bring the Model 1919 bullet at 2,400 f. s., back close to the tower. In one instance, fire with the service cartridge was altered to fire with the Model 1919 bullet at 2,600 f. s. without altering the inclination of the gun, and the bullets continued to return close to the tower. Another instance, however, resulted in no record whatever of the return of the Model 1919 bullet, and it was necessary to take off 25 mils of inclination toward the wind, and add 10 mils of north inclination, which apparently was not affected by the wind, which was then from the east, and blowing 5 miles per hour.

Generally speaking, it is apparently necessary to give the gun about 5 mils inclination for every mile of wind, *i. e.*, a mile of wind equals 17.20 minutes, in contrast to the fact that in horizontal firing at 1,000 yards a mile of wind equals about one minute.

Time of Return

One of the puzzling things about the time of return of the various types of bullets was the peculiar separation of a portion of a long machine gun burst when the Model 1919 boat-tail bullet was fired. A portion of the group would return in about one minute and six seconds whereas the majority of the shots in the burst would not return until one minute and forty-six seconds.

This was taken to mean that this bullet was in a state of delicate balance which was so easily disturbed that the vibration of the machine gun barrel or some other cause, was sufficient to make the majority of the bullets lose their gyro-statie stability at high altitude and return "tumbling" thus unduly prolonging their time of flight. Later experiments showed that this bullet was unstable and that a similar bullet correctly designed had a vertical flight of about one minute and six seconds, thus confirming this interpretation.

"The vertical flight time of the 160 gr., .30-30 blunt-nose bullet at 2,600 f. s. and the very sharp point, 'pencil point' 172 grain match bullet at the same velocity, seems to indicate that the co-efficient of form plays a small part in the actual fight time of a vertically fired bullet. The mean time for the first bullet was 50.4 seconds; for the second 51.4 seconds, a difference of but 1 second, which may be charged to the 12 grain additional weight. The first bullet is very blunt nosed, having a co-efficient of form about .80, and a ballistic co-efficient of .31; the other has a very sharp, slender point, formed of straight lines like a well sharpened pencil, with 'c' value of .50, and a ballistic co-efficient of .53.

"Again we have the 'guard' cartridge, using the service bullet at a velocity of but 1,200 f. s., or 44 per cent of the velocity of the service cartridge, still using up 83 per cent of the time required for the flight of the service bullet—40.8 seconds to 49.2 seconds.

"The tiny .22 Long Rifle bullet, weight 40 grains, velocity 1,050 f. s., ballistic co-efficient .12, requires 72 per cent of the time used by the service bullet, although its velocity is but 39 per cent, and its co-efficient is but 31 per cent that of the service bullet. The reversal of the service bullet in the case, and firing it base first, resulted in its return in 30.4 seconds or ten seconds less than the time of the

Impacts in Hard Beach Sand of Bullets Fired Vertically Upward

Fig. 2. Left. .30 caliber service bullet, returning base first after having reached a height of about 1 3-4 miles and requiring approximately 50 seconds to go up and back

Fig. 3. Center. .30 caliber service bullet fallen on its side instead of its base as the distance from the gun to the impact was sufficient to allow the bullet to half-turn from base-first to point-first

Fig. 4. Right. .30 caliber boat-tail bullet. Time of ascent and descent about 1 3-4 minutes. The bullet returned base first but due to its much greater time of flight and consequent greater height, together with its increased weight, has considerably greater penetration.

'guard' cartridge, showing the retarding effect of the base, and the accelerating effect of the point on the upward and downward trip. This figure agrees exactly with the results obtained by the Germans in firing their own service bullet reversed."

The same tests which were so easy to carry out at Miami were very difficult to execute successfully at Daytona. The method of mounting the gun in the Daytona tests is shown in Figue 1. The gun with armor plate head cover was located over one of the observation bomb-proof dugouts ordinarily used in horizontal firing.

The first surprise encountered on Daytona Beach was that the first tests attempted resulted in nothing ever being heard of the bullets after they disappeared heavenward. As a result, it was necessary to resort to the use of pilot balloon flights. By the use of a great many of these balloons it was possible to have a graphic picture of just what was taking place in the upper air currents at any moment and estimate the correct angle to lay the gun in order that the bullets would return near enough to be heard and later found.

The pilot balloons showed that in the majority of cases the winds at high altitudes were nearly always reversed from their direction on the surface and that it was necessary to lay the gun nearly in the opposite quarter from that required by the surface winds. By this means the tests became more successful and a number of bullets were recovered.

Figure 2 shows the service bullet as it returned after being fired vertically upward. It will be noted that it returned base first although wobbling considerably, and its penetration in the hard sand of the beach is only about one-half of its own length which certainly does not speak well for either its velocity or effectiveness. This bullet returned fairly close to the gun.

Figure 3 on the other hand is a similar test in which the same bullet was used but which landed at a considerable distance from the gun and it will be noted that it has landed squarely on its side thus showing that it was just about at the critical angle already referred to.

Figure 4 shows the hole in the hard sand of the beach made by a returning boat-tail bullet which is rather conclusive evidence of the force with which it returned.

The following table shows the vertical time of flight for various types of weapons as determined at Miami and Daytona, Fla.

SUMMARY OF VERTICAL TIME OF FLIGHT FOR VARIOUS TYPES OF SMALL ARMS AMMUNITION

Ammunition	*Mean Time of Flight*
Caliber .30 Model 1906 (Service):	
Fired from Browning Machine Gun	49 to 51 seconds
Fired from Heavy Barrel in Mann Rest	61 seconds
Model 1919, Boat Tail Bullet, 175 grains, Muzzle Velocity 2,600 feet per second: (Fired from Browning Machine Gun.)	
Main Group	1 min., 46.5 secs.
Abnormal Group	1 min., 6.0 secs.
French Service Bullet, 195 grain, Muzzle Velocity 2,380 f.s., fired in Lebel Rifle	1 min., 11 secs.
Swiss Service Bullet, 175 grain, Muzzle Velocity 2,660 f.s., fired in Swiss Rifle	1 min., 3 secs.
Service Bullet, loaded reversed (point down) in case	31.4 secs.
Model 1919 Bullet, loaded reversed in case	20.9 secs.
180 grain "Palma Match" Cartridge, Muzzle Velocity 2,700 f.s.	57.0 secs.
"Guard Cartridge" Service Bullet, Muzzle Velocity, 1,200 f.s.	40.8 secs.
30-30 Sporting Bullet, 160 grain, blunt nose, Muzzle Velocity 2,600 f.s.	50.4 secs.
Remington "Pencil Point" Match Bullet, 172 grains, Muzzle Velocity 2,600 f.s.	51.4 secs.
Remington .35 Auto-Loading Rifle, Bullet 200 grains, Muzzle Velocity, 2,020 f.s.	57.3 secs.
Caliber .22 Long Rifle Lesmok, Bullet 40 grains, Muzzle Velocity 1,050 f.s.	35.6 secs.
Model 1911, Caliber .45 Automatic Pistol, Bullet 230 grains, Muzzle Velocity 800 f.s.	39.0 secs.

(Note.—This is the average time it takes the bullet to pass from the muzzle of the gun vertically upward and return to earth.)

Based upon various foreign calculations as to the duration of time that the bullet occupies in various portions of the path in its upward flight and the height to which it ascends the following estimate is made for the service bullet. The service bullet probably ascends to about 9,000 feet, requiring about 20 seconds to ascend and about 35 seconds to descend. The bullet probably descends the last 6,000 feet at a nearly constant velocity of about 300 feet per second, as the bullet is subject to increasing resistance to its motion due to the fact that the density of the air increases as the surface of the earth is approached. Otherwise the velocity of the bullet would continue to increase due to the effect of gravity.

It is therefore quite easy to see why it is so hard to observe the return of bullets which have been fired straight up, as the bullet must spend something like seventeen or eighteen seconds on the way up at altitudes above 1,000 yards while on the way down it similarly requires something like twenty or more seconds of time to reach an altitude of less than 1,000 yards. As has already been shown, the winds at altitudes above a few hundred yards are often reversed in direction from that of surface winds and meteorological reports show that the average winds at heights above 1,000 yards are around twice the velocity of the surface winds. Also the upper currents are often several times as strong so that when it is quite calm at the surface it may be very windy a few hundred yards up. This was shown time and again in the tests of horizontal firing at long ranges.

Certain conclusions may be drawn from these vertical firing tests which will be briefly stated as follows:

I. Bullets when fired straight up usually return with a slight hissing or humming noise. While in a vacuum they would return in the same path and with the same velocity they had when fired, actually the path is quite different and the velocity very low.

II. The striking energy of the falling service bullet appears to be only about half sufficient to cause a casualty. In fact the bullet will not bury itself in hard sand, it usually being found, point up, half projecting from the sand and apparently having about the same penetrative ability as it possesses at ranges on the horizontal from 2,800 yards to the end of its trajectory (3,300 yards).

III. When fired automatically from a machine gun, sometimes the bullets return in regular sequence, and at other times they bunch, several bullets falling at once. This, of course, is due to variations in the time of flight.

IV. A properly balanced bullet will return base first, showing that it retains its "spin."

V. Neglecting the effects of spin on the center of gravity, the shape, weight and muzzle velocity of small arms bullets apparently have a relatively small effect on the vertical time of flight, compared to the effect produced in horizontal firing.

VI. The coefficient of form (c) does not affect appreciably the time of flight.

VII. When the horizontal distance to the point of impact on the ground exceeds several hundred yards, bullets will be found to strike on their sides, and at greater distances will be pointed downward.

VIII. While the maximum vertical range for service ammunition is somewhere around three quarters of the maximum horizontal range yet the theoretical maximum vertical range at which fire can be effective is almost as great as the maximum effective range on the horizontal. Practically, however, it is doubtful if an aerial target can be effectively covered at ranges much in excess of 1,000 yards if this great, due to the almost insurmountable difficulties of hitting such a target, even with machine guns.

Aircraft Armament Division Notes

The last Aircraft Armament Division Notes were published in the May-June number of ARMY ORDNANCE but since then, in nearly every issue, an article has appeared covering the more important activities of the Division.

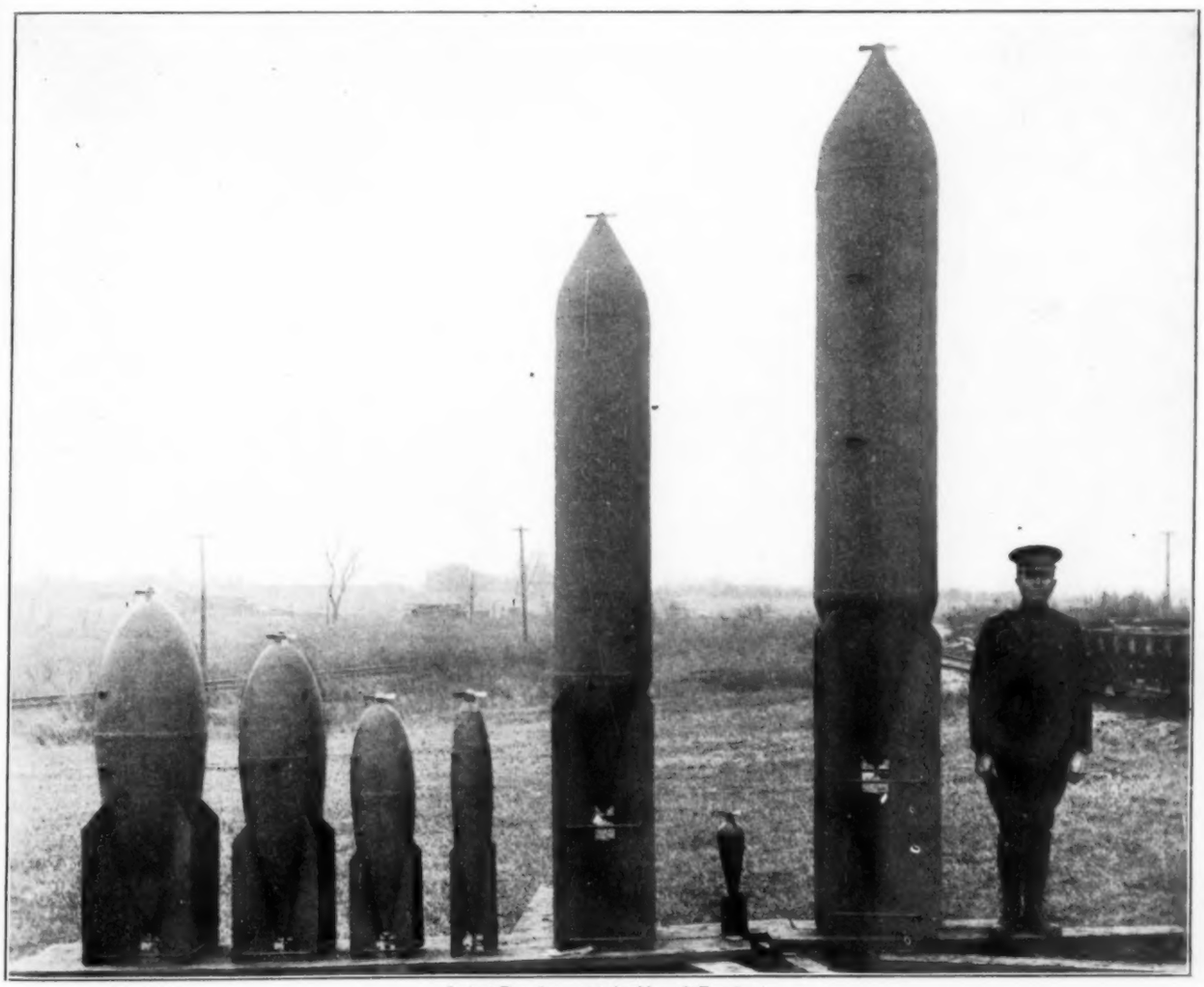
Bombs: From these articles it will be apparent that considerable progress has been made by the Division in the development of bombs, as evidenced by the success attained in the sinking of the ex-German naval vessels in June and July and the ex-U.S.S. "*Alabama,*" in September. The bombs successfully used in these tests were the following:

300-lb. Demolition Bomb, Mark I MI.
600-lb. Demolition Bomb, Mark I MI.
1100-lb. Demolition Bomb, Mark III.
2000-lb. Demolition Bomb, Mark I.

Since these tests, this Division has been occupied in completing the final drawings of the bombs and fuses in order to get them approved for standard issue to the service. During this period, a small number of 100, 300 and 600-lb. Demolition Bombs of the latest design have been produced and are now at Aberdeen Proving Ground, awaiting test. In addition, a small quantity of the thick case type of Demolition Bomb in the 100, 300 and 600-lb. sizes have been completed and are at Aberdeen Proving Ground being tested. These latter bombs have cases of cast metal. The cases in each size are made of four different kinds of metals and tests run are to determine which metal is best. In addition to the types of Demolition Bombs, the new type of 25-lb. Fragmentation Bomb has been manufactured in small quantities and some of these have been completed and are at the Proving Ground being tested. All these types of bombs are shown in their latest development in the accompanying illustration.

The Aircraft Armament Division has recently undertaken the design of a 25-lb. Gas Bomb. An order for a few of these bombs is about to be placed and preliminary tests will be held in the near future.

Various tests are being run on fuses for bombs to ascertain the strength of various parts. Some improvements are also under investigation and a small order is being placed for an improved type of nose fuse and improved type of tail fuse for Demolition Bombs, based on the design of the fuses which were used in the battleship bombing tests. There are additional types of fuses under development such as the long delay and special operations, selective delay and standard types in which the ellipsoidal booster will be used and the firing pin will be kept out of line with the primer until the bomb has been released. Considerable progress has been made in the development of these fuses and some are at Aberdeen Proving Ground being tested. It has been deemed advisable to transfer the bomb fuse development work from Frankford Arsenal to Picatinny Arsenal and this transfer has just recently been effected. A good deal of the bomb development work will also



Latest Developments in Aircraft Bombs
1100-lb., 600-lb., 300-lb., 100-lb., 2000-lb. demolition; 25-lb. fragmentation; 4000-lb. demolition

be undertaken at Picatinny Arsenal, where all the loading of bombs is accomplished.

In connection with the fuse development, further difficulty has been encountered in evolving primer-detonators to give delay action. A very exhaustive study is being undertaken on this subject in the expectation of reaching an early solution of the difficulties. The primer-detonators used in the battleship bombing tests functioned very satisfactorily, but recently a large number of failures have been obtained in the longer delays under development. It is hoped, however, to overcome the difficulties in the very near future.

In connection with the manufacture of the heavy case Demolition Bombs, Watertown Arsenal is manufacturing the semi-steel case of the bomb body. Watertown Arsenal has worked out a very ingenious method of casting these bomb bodies and although only a few castings have been produced, there is every indication that there will be no further difficulty in producing bomb bodies from semi-steel by the method developed at Watertown. The work being done there is particularly commendable in that a large number of commercial concerns were approached on the casting of these bombs and none would undertake the order.

Watervliet Arsenal is completing the assembly of the heavy case bombs. The bombs produced at Watervliet and received at Aberdeen are by far the best bombs of the type which have been produced and are superior to samples of cast bombs received from abroad.

Rock Island Arsenal has done excellent work in the manufacture of the Mark III series of Demolition Bombs. In connection with the manufacture of these bombs, Rock Island Arsenal has prepared a book covering the operations undertaken in the production of these bombs and these books have proved extremely valuable to the Division in completing the drawings of the bombs and writing up the specifications. These books will be valuable in the event of war when production must be undertaken by commercial manufacturers.

Frankford Arsenal has, until just recently, done all the fuse work for the Division and produced the 2,000-lb. bombs for the battleship tests. In a very short space of time this Arsenal also produced a small quantity of 4,000-lb. bombs, one of which was tested at Aberdeen in October and found to be entirely satisfactory. Tests on the 4,000-lb. bombs are to be continued.

At Picatinny Arsenal all loading of bombs has been undertaken, and this Arsenal has done excellent work in loading the large number of bombs which were needed for the battleship tests and also in loading the 4,000-lb. bombs which had to be gotten out in a very short space of time.

The Bureau of Standards has continued its work on testing the ballistic models which have been produced for test in the wind tunnel. Very valuable results are being obtained. The testing of various forms of fins is shortly to be undertaken.

At Aberdeen two camera obscura buildings are being constructed, and it is hoped to start work on bomb ballistics at that station early in the new year.

Bomb Sights and Bomb Racks. In accordance with General Order No. 6, War Department 1921, the transfer of bomb sights and bomb racks to the Air Service was effected June 30, 1921. Two of the Bomb Sight projects were continued in the Ordnance Department until the completed sights and stabilizers could be turned over to the Air Service. Work on these two projects is continuing satisfactorily.

Aircraft Machine Guns. The Colt Company has completed four of the 1921 model of the .50-caliber aircraft machine gun. These models are undergoing extensive tests and, to date, indications are that this model will be a very successful weapon. An order for a small number of additional guns of this model is being placed with the Colt Company to be used for test in the service. A .50-caliber aircraft gun, model 1922, has also been completed by the Colt Company. This gun has provision for right and left hand feed and is provided for mounting interchangeably either on the right or left hand side of the airplane, as desired. This model gun, although functioning very well, required a considerable number of additional spare parts and therefore the development of a model 1923 gun was initiated for the purpose of getting a gun which would feed both from the right and left hand side and which would not require spare parts for the interchangeable feature. A design of this gun has been completed by the Colt Company and one gun is being manufactured. If this gun proves satisfactory, two more guns will be constructed and tested.

A contract has been placed with the Savage Arms Company to develop improvements in the Lewis Gun with the purpose of obtaining a more positive functioning mechanism. One model will be constructed and tested. In this work effort is being made not to include extensive modifications but only such changes as can be undertaken on existing guns so that in the event a satisfactory modification is worked out, all guns in the service may be modified.

The construction of one model of 1919 Browning .30-caliber gun is being expedited at Springfield Armory. When this gun is completed and if it is found satisfactory, a small number of additional guns will be constructed for extensive tests. If these guns prove satisfactory, a larger number will be produced for service test. It is planned to use this gun as a basic design for production in case of an emergency. In addition, a .30-caliber aircraft gun is being developed at Springfield for right and left hand feed and installation. One model of this gun has been completed and tests on it have started.

Development of rounds-counters for synchronized guns has been receiving considerable attention. These rounds-counters are for the purpose of indicating to the pilot of the airplane the number of rounds fired and the number remaining in the magazine. Two types are being investigated, one in which a pointer moves over a dial and the other, a counter which registers in a manner similar to the mileage indicator on an ordinary speedometer.

37 mm. Aircraft Guns. After considerable work on the 37 mm. Baldwin Gun, a final test was held this past summer with this weapon in which it was demonstrated that satisfactory results could never be expected from this gun and therefore work on it was cancelled. Since then, a study has been undertaken by the Artillery Division of the development of a 37 mm. full automatic gun for use in aircraft. The design of a pilot model has been approved and is under construction at Watervliet Arsenal.

The Colt Company has not as yet decided definitely to undertake the development of a full automatic 37 mm. Aircraft Gun. It is hoped that they will undertake this development, as their knowledge of automatic arms is so extensive that by applying the principles to the 37 mm. gun, it is likely that a satisfactory weapon can be produced. Other sources are being approached with the idea of interesting concerns in the development of this gun.

On request of the Air Service, a modification is being developed for the 37 mm. semi-automatic motor cannon, model 1918, so that it can be mounted for firing as a free gun. Work has progressed on this study to the point where the manufacture of one modified gun is shortly to be undertaken. If it proves satisfactory, sufficient additional guns will be modified to equip airplanes in service which will carry this gun.

Miscellaneous. This Division has obtained for the Air Service, a 3-inch Davis non-recoil gun for test by them at McCook Field, Dayton, Ohio. This gun is now undergoing test at that place. Negotiations have been entered into with Commander Cleland Davis, U.S.N., Retired, the inventor of the Davis non-recoil gun, for the purpose of obtaining for test a 5-inch gun of this type. If this gun withstands proof-firing satisfactorily, it will be furnished to the Air Service for trial in the air.

During the past few months, re-assignment of work in the Aircraft Armament Division has been possible through the transfer of bomb-sights and racks to the Air Service and to the assignment of several additional officers of the Division. Captain Loring has been transferred from Frankford Arsenal to Washington and is now handling all of the work pertaining to bomb ballistics, and is acting as consulting engineer for the Division. Captain T. M. Jervey, formerly with the Aircraft Armament Division in France, was transferred to the Ordnance Department and assigned to this Division. He is in charge of aircraft machine gun and cannon development work in the Division. Captain E. E. MacMorland of the Ordnance Department, was transferred from Muscle Shoals and is now in charge of the Administrative Section of the Division.

The Dayton Branch Office of the Division has been disbanded and Captain W. T. Gorton has been transferred from Dayton to Springfield Armory where he is now carrying on the experimental work on aircraft machine guns. Captain Gorton is being assisted by Lieut. R. C. Coupland who has been recently assigned to Springfield Armory. Captain Frank Short has been transferred from Frankford Arsenal to Aberdeen Proving Ground where he is working on the ballistic test equipment for bombs.

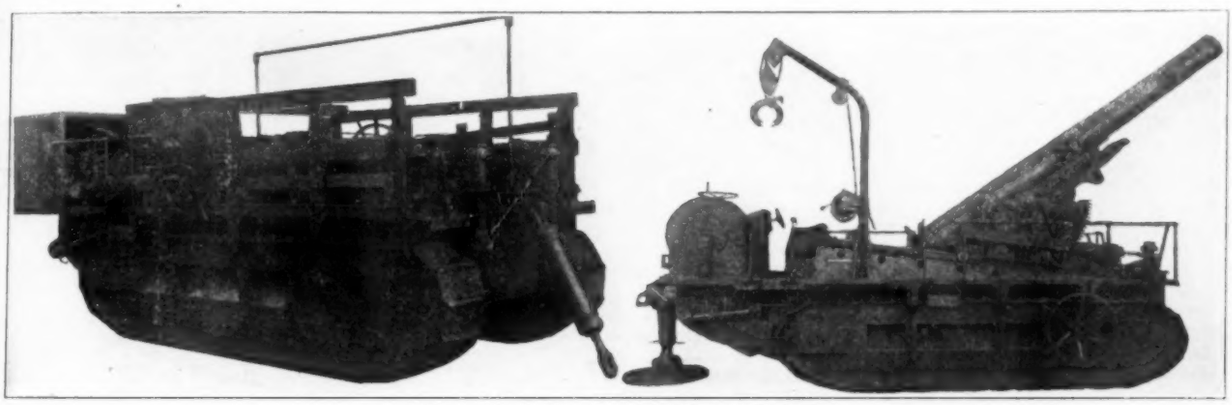
The testing facilities at Aberdeen Proving Ground have been increased by the addition of the dirigible "C2." Preliminary bombing tests with this dirigible indicate that very satisfactory results can be expected in dropping bombs from this ship on the hard surface area and test building. It is believed that this method of testing will be a decided improvement over that in which the observation balloon is used.

Artillery Division Notes

Tests of the 240 mm. Howitzer Motor Carriage Mark IV and IVa

Tests were conducted recently at the Aberdeen Proving Ground of the 240 mm. Howitzer Motor Carriage Mark IV and IVa, for the purpose of studying the operation of the gas-electric power plant and transmission with which these vehicles are equipped. Representatives of the General Electric Company assisted at the tests and gathered much useful information as to the characteristics of the equipment upon which will be based a design study for a similar type of power plant and transmission for the 240 mm. Howitzer Motor Carriage, Model 1923.

The 240 mm. Howitzer Motor Carriage Mark IV and IVa is a two vehicle type of unit, one vehicle mounting the howitzer and the other the gas-electric power plant which supplies electric power for propelling both of the vehicles, the power to the gun carriage being transmitted through a flexible two-wire cable. Each vehicle is equipped with two driving motors, one for each track. The accompanying illustration shows the general appearance of the two vehicles. This motor carriage was built in the United States from a French design developed by the St. Chamond Company of France during the World War and only modified to suit American equipment and standards.



240 mm. Howitzer Carriage, Mark IV and Mark IVa

Gas Electric Power Unit — Howitzer Unit

The tests, which were preliminary to a more elaborate series of tests, demonstrated that the gas-electric system as applied to these vehicles has a number of serious defects which must be modified to insure satisfactory operation on army vehicles. The performance of the various units of the electric system was satisfactory, the motors, the generators and controllers all functioned properly. The arrangement of the control group, however, was found to be such that the operator was required to devote too much attention to handling levers at critical times. A rearrangement of the control group was found to be necessary to insure satisfactory operation.

The arrangement of the control group had a direct effect on the performance of the power plant at times when maximum output was necessary. When turning in soft ground, the gas engine usually stalled, due to the fact that the operator could not handle the control lever quickly enough to reduce the generator load. Under such conditions the engine governor was too slow in operation to give proper engine speed in proportion to power demand. A regrouping of the control group, with proper engine governing will eliminate this difficulty and provide sufficient power under any condition of operation.

An interesting result of the test was the fact that the series driving motors with which the vehicles are equipped, cannot utilize the full available power of the power plant when travelling on level ground. In order to utilize the maximum output of the power plant, it was determined that a change in the gear ratio from motor to track would be advisable if the maximum output was to be utilized when travelling on level ground—the driving motors operating at the highest speed under this condition. When operating over rough ground or up steep grades, or when turning, the higher motor torque required will cause a reduction in speed of the vehicle. Under these conditions the gas engine will not stall since the simplified control group will operate to prevent it.

The results to be obtained with the new equipment are to proportion the power plant to give the specified speed of vehicle under average conditions of operation and to have proper control of the power plant to insure the engine not stalling under adverse conditions.

Springs on German 105 mm. Howitzer Materiel

The German 105 mm. howitzer matériel that was received after the armistice and returned to the United States has been found to be of great interest from an engineering viewpoint. The general type of the matériel is superior, but the design of many parts is such that manufacture would be difficult, and it seems evident that the designer was able to rely upon careful and painstaking manufacture. The fabrication of many parts presents examples of very good forge and machine shop work, which it would be difficult to obtain in quantity production here, except at great cost. The Ordnance Department was especially interested in the helical steel springs used in this matériel, since it has been very difficult to secure steel springs of a corresponding grade in this country.

When the 105 mm. German howitzer is fired, it is returned to battery by the counter recoil springs. The spring column consists of inner and outer springs of round cross-section. The specifications for these springs are as follows:

COUNTER RECOIL SPRINGS

	Outer.	Inner.
Size of bar, inches (diameter)	.593	.531
Outside diameter, inches	6.125	4.375
Free height, inches	29.875	28.375
Solid height, inches	7.125	9.3129
Load solid, pounds	2020	2290
Fibre stress, lbs. per sq. inch	137,000	150,000

The trunnions of the cradle are placed near the rear end and it is necessary to balance the tipping parts to readily elevate or depress the howitzer. This balancing is done by a spring equilibrator, under the cradle. The helical springs used are of square cross-section. To make the spring of square cross-section it is necessary to roll the bar to a keystone section, which becomes square when the spring is coiled. The specifications for these springs are as follows:

EQUILIBRATOR SPRINGS.

	Outer.	Inner.
Size of square bar, inches	.718	.593
Outside diameter, inches	5.812	3.75
Free height, inches	28.125	18.812
Solid height, inches	9.5	8.6
Load solid, pounds	5750	5950
Fibre stress, lbs. per sq. in	190,000	217,000

A section of each of these springs was given a chemical analysis at Watertown Arsenal The results as compared with commercial steels are given in the table on page 244.

Note. The high fibre stress that is obtained by heat treating.

	Carbon	Manganese	Silicon	Sulphur	Phosphorus	Molybdenum	Chromium
Counter Recoil Spring —Inner	.55	.97	1.625	.038	.066		.09
Counter Recoil Spring —Outer	.55	.71	1.08	.041	.050		.04
Equilibrator Spring—Inner	.485	.55	3.315	.017	.041		.09
Equilibrator Spring—Outer	.48	.70	3.125	.020	.040		.02
S. A. E. Silico—Manganese 9250	.50	.70	1.95	.045	.045		
S. A. E. Silico—Manganese 9260	.60	.60	1.65	.045	.045		
Freight car truck springs*	.45	.50	.25	.045	.04	.40	.95

*Proposed tentative specification for chrome molybdenum alloy steel helical springs by the Mechanical Division of the American Railway Association.

The equilibrator springs which develop the high fibre stresses have a small sulphur content and a large amount of silicon as shown by the tabulation.

Watertown Arsenal Notes

Method of Traversing 14-inch Railway Mount, Model of 1920, by Means of Large Ball Bearings.—On seacoast gun carriages designed for permanent emplacement at fortifications, the guns and carriages rest on large base rings necessitating a great many heavy conical rollers held in distance rings, as well as a large racer to obtain a complete turn table or means for traversing in azimuth.

Due to the fact that these huge parts are emplaced on solid concrete foundations, the weight is not of first importance. When "all-around fire" is desired on a railway mount, which must of necessity be mobile, and capable of being placed in any position desired, the pintle, or means to provide motion in azimuth, must be of the very lightest design.

The Artillery Division, Railway and Seacoast Carriage Section of the Army Ordnance Department has introduced in the 14-inch Railway Mount, Model 1920, a ball bearing of dimensions and under specifications as described below, and as in the accompanying photographs. Aside from the introduction of large ball bearings to act as a turn-table for moving the gun and carriage in azimuth there have also been introduced in that carriage many novel features which have been described in a previous issue of ARMY ORDNANCE by Col. G. M. Barnes of the Ordnance Department.

The ball bearing as illustrated in this article, or as it is called in the Ordnance Office drawing, the "lower pintle thrust bearing," consists of an upper race, a lower race and 40 balls. Both races are of the same dimensions 56.25 inches outside diameter, having a tolerance of +.003, —.000 while the inside diameter is 46 inches +.000, —.003 and the thickness overall is 2.75 ± .01. The balls are 4 inches in diameter and require an accuracy of + .0003.

The races as well as the balls were made of chrome bearing steel, hardened and ground, and test for hardness developed a Shore sceleroscope in the races and balls of 90 points and better.

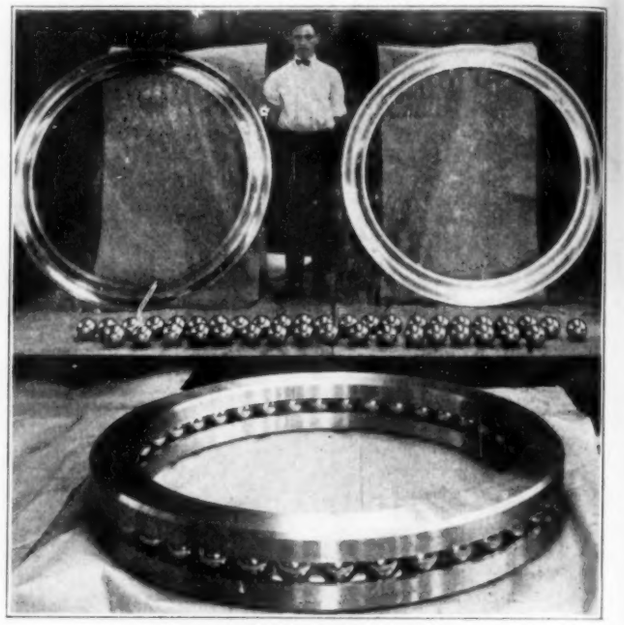
The races are capable of carrying a sustained load of 100,000 pounds on one ball applied at any point in the circumference of the groove and each ball will stand a load of 100,000 pounds when placed between the finished races without showing any permanent deformation or surface cracks.

The balls were tested by the manufacturer under a Reihle testing machine using the three-ball method, wherein three balls are superimposed, the center ball being the one actually under test. The three-ball method has proven itself to be the most reliable of testing, and is replacing the old way of testing one ball between two hardened steel plates, this three-ball method being more severe, due to the fact that the ball under test is only supported by an actual point of contact instead of two flat surfaces, and the results are therefore more accurate, consistent and reliable.

The formula used by the manufacturer for crushing strength of steel balls under the three-ball method is $1000xD^2$ where D represents the diameter of the ball in one-eighth inches. This would mean that the 4-inch balls would crush at a load of about 1,024,000 pounds, while the design requires only a strength of 100,000 pounds, so that an ample factor of safety was thus obtained.

From the above analysis of this large ball thrust bearing, it would thus be possible to subject it to a perfectly safe load of 4,000,000 pounds, providing the stresses were equally divided on all the balls, and it would deform under a load of 40,960,000 pounds under a uniformly distributed stress.

The static load on this thrust bearing, that is, the weight of the gun and the mount not including the four trucks, and of course, not including the maximum component due to the powder pressure at the highest elevation, is about 550,000 pounds.



Ball-bearings for 14-inch Railway Mount
Manufactured by Standard Machinery Co., Auburn, R. I.

That light thrust bearings for railway mounts in comparison with heavy bearings required for gun carriages in permanent seacoast emplacements are satisfactory in every respect was clearly demonstrated at a recent firing of a 12-inch Railway Mount, Model 1918, at the Aberdeen Proving Ground. The light platform or thrust bearing was found to be entirely satisfactory for the purpose. The base ring racer and rollers taken from a 10-inch Disappearing Carriage, Model 1896, although of comparatively small dimensions, sustained satisfactorily the stresses produced by a 12-inch Gun, Model 1895, fired in the horizontal position, using a 700-pound projectile and full muzzle velocity.

Student Research at Watertown.—The Student Research Plan was inaugurated at Watertown Arsenal in the fall of 1920. It consisted of an arrangement whereby graduate students at Harvard University and Massachusetts Institute of Technology were allowed to work out research metallurgical theses at the Arsenal. Some of the problems were assigned by the institutions concerned and the others by the Arsenal. Three officers of the Ordnance Department, doing graduate study at M. I. T., were also included under this plan.

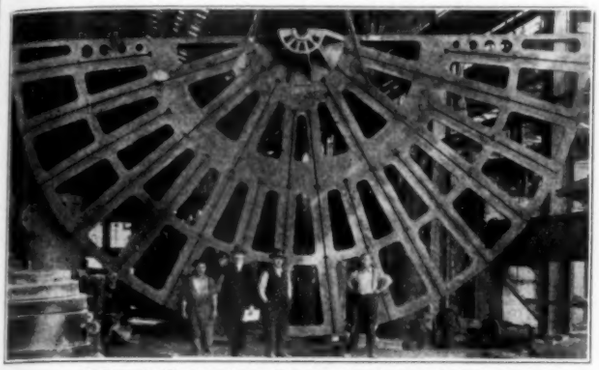
The researches were along the following lines:

(1) The Effect of Repeatedly Heating Steel Castings Through the Critical Range.
(2) Study of the Dendritic Structure of Hypo-Eutectoid and Eutectoid Steel.
(3) Study of the Carbides in Nickel Chrome Steels of Various Heat Treatments.
(4) Melting Metals in Vacuo.
(5) Resistance of Steel to Repeated Stress.
(6) Tensile Properties of High Speed Steel at Various Temperatures.
(7) Effect of Heat Treatment upon the Impact Properties of Nickel Chrome Steel.
(8) Study of Chrome Molybdenum and Nickel Chrome Molybdenum Steels.

Seven civilian students and three student officers worked upon these problems. Approximately 3217 hours of work were done at the Arsenal and institutions exclusive of reference work.

The co-operation between the students, educational institutions and the Arsenal was excellent. The students, with one exception, were eager and intelligent workmen. The results obtained from the researches are valuable, and, where they are not conclusive, are helpful stepping stones to future conclusive results.

In addition to the direct advantages of this work to the Arsenal and the Ordnance Department, there are also the indirect advantages of familiarizing graduate engineers with some of the problems and work of the Ordnance Department, thus preparing them for Government service in the time of an emergency. This work is of advantage to the educational institution and student because (a) it tends to co-ordinate theory and practice and (b) it gets the student into real manufacturing atmosphere.



A Sample Casting from Watertown Arsenal Foundry

Half of a face plate for an internal and external gear cutter designed to cut gears up to 42 feet in diameter—molded and cast at Watertown. Weight 30,000 lbs.

Frankford Arsenal Notes

The program laid out by the Ordnance Office for an increased production capacity in the three different Arsenal manufacturing departments, the Small Arms Ammunition, the Artillery Ammunition, and the Instrument Departments, utilizing to the fullest extent all manufacturing buildings, including also the construction of three new large buildings for the Artillery Ammunition Department, and one building for experimental work, was completed during the past summer. The shops in these departments are now up-to-date in every respect and are well equipped with the latest and finest types of machinery and equipment for the different processes of manufacture. Practically all of this machinery and equipment, also the materials used in the installations, were obtained from salvage. The capacities for manufacture are the maximum that the buildings afford, and are far in excess of the present schedule. In the event, however, of another emergency, Frankford Arsenal will be a far more important factor, insofar as quantity production is concerned, than during the past emergency.

Only a few figures are necessary to show how the Arsenal has grown since the start of the European War. In 1914 there were 92 buildings, with a total floor area of about 500,000 sq. ft., and at present there are 152 buildings, with a floor area of 1,400,000 sq. ft. The present area of the Arsenal is 91 acres, 81 sq. rods, of which a plot of 28 acres, 4 sq. rods was acquired by purchase in 1917. There are 5 miles of roads, and 3¼ miles of railroad sidings.

A new power plant is under construction, the building being completed, but the installation of equipment has not yet been started. The power transmission system is also being changed from low-tension at 220 volts to high-tension at 2300 volts. During the past emergency the present power plant was totally inadequate, and the new power plant and the new transmission system are greatly needed improvements.

Bids are being taken to utilize appropriations on hand for the construction of two double sets of quarters for officers, and one double set of quarters for noncommissioned officers.

Artillery Ammunition. During the past year the Artillery Ammunition Department at Frankford Arsenal has been particularly active in the manufacture of Demolition bombs and Bomb Fuzes for the Army Aireraft Service. The Department modified bombs of the 100 lb., 300 lb., and 600 lb. types, and also manufactured all fuzes and adapter boosters required for the same. The initial lot of 2,000-lb. Demolition Bombs which were used in extensive tests conducted off Chesapeake Bay, and which were remarkably successful against captured enemy vessels, were manufactured at this Arsenal. The latest achievement in Demolition Bomb work is the 4,000-lb. type, which was also manufactured here. The recent tests conducted at Aberdeen Proving Ground also proved this type to be a perfect success in so far as the proper functioning of all mechanism and explosive action is concerned. Further tests are contemplated against vessels at sea. There are also being manufactured in the Artillery Department various experimental types of shells and proof slugs from 1.8-inch to 8-inch caliber. Among these shell are various innovations that are being tried for their greater efficiency and less cost over the standard or recognized types of shell previously used. Several types of Point Detonating Fuzes new to the service are also being manufactured for use in the above mentioned shell. Preparations are being made for the manufacture of a large quantity of base detonating fuzes for use in seacoast ammunition.

Experimental Fuzes. The following development work has been undertaken by the Artillery Experimental Department:

A major caliber armor-piercing base-detonating fuze for major caliber projectile. This fuze has proven entirely satisfactory in extensive firing tests which have been conducted with it. This fuze is "bore-safe" and has been accepted by the department for use in all major caliber armor-piercing seacoast projectiles.

A superquick and automatic selective mechanical delay point-detonating fuze for all calibers from 75 mm. to 12-inch inclusive. This fuze is so designed that it will explode the projectile just after it emerges from its resistance, regardless of what the thickness of the resistance may be, but if the projectile cannot penetrate the resistance which it hits, as will be the case when fired directly into the side of a hill, the fuze will explode the projectile when it is finally stopped. In addition to this selective action the fuze can be made superquick at the option of the gunner. This fuze is also entirely "bore-safe."

A superquick point-detonating fuze for all calibers from 75 mm. to 12-inch inclusive. This fuze is "bore-safe" and will give extremely quick action as the projectile will be in front of its resistance when detonated.

A superquick and non-delay point-detonating fuze. This fuze is "bore-safe" and will give either superquick or what is known as non-delay action at the will of the gunner. By non-delay action is meant a very slight delay sufficient to permit the projectile to just get through a 4-inch wood plank before it detonates.

A superquick and short delay or superquick and long delay point-detonating fuze. This fuze can be assembled with either a short delay or long delay. The gunner can obtain either a superquick and short delay action or superquick and long delay action depending upon how the fuze is loaded. This fuze is for use for mining action at long range and for richochet action at short range against personnel.

A non-delay action base-detonating fuze for 2.24-inch armor-piercing projectile has been developed and is practically perfected. This fuze is "bore-safe" and gives just sufficient delay to enable the projectile to pass through light armor.

A time detonating fuze for anti-aireraft artillery has been developing and is practically perfected. This fuze is "bore-safe" and is designed to give superquick detonation upon impact or time detonation in flight.

A detonating element for use with mechanical time fuzes. In combination with the mechanical or powder time fuze, this element makes it possible to obtain either a non-delay action upon impact or time detonation in flight. This element is "bore-safe."

A supersensitive superquick point-detonating fuze for 37 mm. high explosive ammunition. This fuze is bore safe and is extremely sensitive. It will explode the shell upon impact with aeroplane linen. It will be used against aeroplanes, balloons and dirigibles.

During the past year considerable development work on 37 mm., 1.8-inch and 2.24-inch armor-piercing projectile has been carried out. Satisfactory results have been obtained with all three calibers. A satisfactory 37 mm. canister has also been perfected.

In addition to the development of artillery ammunition, the Experimental Department is engaged on the development of special fuzes for drop bombs for the Aircraft Armament Division of the Ordnance Office. At the present time there is a total of five (5) different types under development as follows:

A long-delay nose-fuze and a long-delay tail-fuze for use in all sizes of drop bombs. These fuzes are designed to give a delay varying from 2 hours to 36 hours. The delay desired is obtained at will by the operator. This means that the bomb is dropped and at a definite time thereafter, the bomb will explode. Should the enemy attempt to remove the fuze from the bomb during the interval between the time it is dropped and the time it is set to explode, the fuze will immediately explode the bomb, killing the one who attempts to remove the fuze and destroying all evidence of the design. The object of this design is to keep the enemy out of a vital area and thus prevent them from making repairs to railroad tracks, roads and the like, which have been destroyed by the bombs. These fuzes are made perfectly safe in handling by the same method as is used in obtaining "bore-safe" action in artillery fuzes.

An instantaneous and selective-delay tail-fuze and an instantaneous and selective-delay nose-fuze for all calibers of drop bombs. This fuze will be designed with instantaneous action and three separate delays. The bomb can then be dropped to give any one of the four desired actions. This fuze is made entirely safe in handling, transportation and storage.

An all-ways nose-fuze and an all-ways tail-fuze. These fuzes are for use on drop bombs of all calibers and for use with aerial torpedoes. This fuze will explode the bomb or torpedo instantly upon impact, no matter how the bomb hits, that is, the fuze will function if the bomb hits on its side, on its nose, or on its tail. This fuze is made perfectly safe in transportation and in storage.

A special-operations tail-fuze and a special-operations nose-fuze. This fuze is designed to function a definite distance from the plane and then to explode after a definite time delay. This fuze is also for use in all calibers of drop bombs and is made safe in transportation and storage.

A selective nose-fuze. This fuze is designed to explode instantly upon impact with a heavy resistance, but to explode with a pre-determined delay after a light impact is encountered. This fuze is for use in all calibers of bomb and is made safe in transportation and storage.

Fire Control Material. The Wilson Range Computer which has been under development at the Arsenal for some months past, has now been completely assembled and is ready for test problems. As its name indicates, this device is an apparatus for computing the range and azimuth of a target, having given the length of a base line and the two azimuth angles from its ends. It is universal in its operation, or in other words, will perform its functions under all practicable conditions in regard to location of target with respect to base line, length of base line and location of base line with respect to the battery. The solution of the problem is obtained, as in a plotting board, by reproducing on a small scale, the triangle made by base line and target. In the Wilson Computer, however, the scale is very small, viz., one inch equals 5,000 yards, and the device is therefore quite compact, although capable of computing ranges up to 50,000 yards.

The New Optical Plotting Board which is now under construction at the Arsenal is designed to solve the same problem as the Wilson Range Computer. In this case, however, instead of using material arms for the reproduction of the sides of the target-base line triangle, rays of light are employed to determine when the moving parts are in the proper position. The optical board will also be practically universal in its operation, and very much more compact than a plotting board of the same capacity. It is expected that the optical board will be completed by December 1st.

New Sights for Gun and Howitzers. The Ordnance Department has recently completed several new designs of gun carriage for use with field artillery. These carriages were equipped with new designs of sighting equipment hereinafter described.

Figure 1 shows the Sight Mounting, Type P, for the 105 mm. Howitzer Carriage, Model of 1921 E. This sight mounting is of the automatic azimuth correcting type, compensating for cross level angle of ten degrees in either direction at 45 degrees elevation. The sight support, F, is designed to receive the Panoramic Sight, Model 1917, with the modified fastening. It is fastened to the cradle trunnion by means of the bolt A and keys B. Bracket C is attached to the rocker, holds the sight carrier in an upright position and supports the cross-leveling rack K which is operated by the cross-leveling knob D. H is the cross-level and J the longitudinal level by which means the rocker is kept level when the gun carriage is being used for indirect fire. The lever G extracts the Panoramic Sight from the support F at E.

Figure 2 shows the Range Drum, Type C, for the above mentioned carriage. The Range Drum, Type B, for the 75 mm. Gun Carriage, Model of 1921E, is practically the same as the Type C Drum, except that the methods of fastening to the cradle trunnion are different. The range scale A is held on the range drum body B by means of the clamps C, which afford easy means of adjusting the scale with respect to the pointer D. The drum is rotated by a system of gearing which is attached to the cradle trunnion. Forty-five (45) degrees elevation of the cradle moves the drum through 360 degrees. The pointer D is attached to the angle of site scale E by which means the pointer is rotated through an angle equal to the angle of site. The worm housing F is rigidly attached to the rocker of the carriage. The graduations shown on the scales are in mils. The blank spaces on the drum will be graduated in range corresponding to four zones which have not yet been determined.

Figure 3 shows the Sight Mounting, Type N, for the 75 mm.

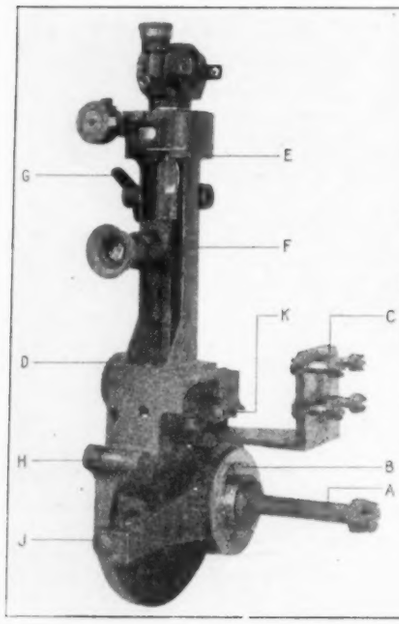


Fig. 1

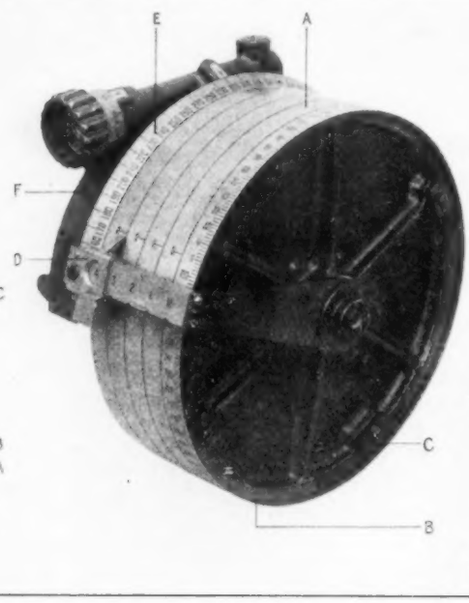


Fig. 2

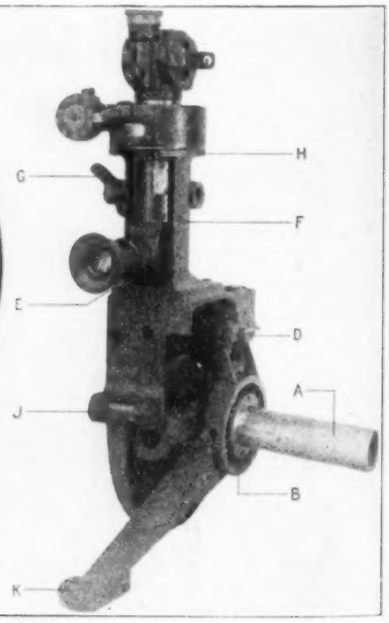


Fig. 3

Gun Carriage, Model of 1921E. This sight mounting is practically similar to the Type P Mounting except that the methods of attaching to the cradle trunnion differ and the sight support F is shorter. The stem A which carries part of the universal joint is forced into the cradle trunnion and pinned. The bracket B is attached to the rocker trunnion, holds the sight carrier in an upright position and supports the cross-leveling rack D, which is operated by the cross-leveling knob E. J is the cross-level and K the longitudinal level by which means the rocker is kept level when the gun carriage is being used for indirect fire. The lever G extracts the panoramic sight from the sight support F at H.

Experimental Musket Sight. An experimental lens sight has been made for the U. S. Rifle, caliber .30, Model 1903. This is for use in conjunction with the Lyman No. 48 receiver sight, or other similar types of sight being manufactured experimentally at Springfield Armory. A cup disc containing the rear lens screws into the aperture of the receiver sight. A hooded container carrying the front lens clamps securely over the barrel at the front sight stud. Both can be readily removed leaving the non-magnifying sights without change. This lens sight gives a magnification of three diameters, with a large clear field. It will be tested by The Infantry Board with a view to determining its suitability for sniping purposes.

National Match Ammunition. It is particularly gratifying to note the excellent results obtained with 1921 National Match Ammunition at the National Matches held at Camp Perry, Ohio, August 27th to September 24th. This ammunition was manufactured at Frankford Arsenal, and arsenal tests had shown it superior in accuracy to any machine made small arms ammunition heretofore made anywhere. In fact it gave groups less than half the size given by any other ammunition, and equalled in accuracy the hand loaded, laboratory made ammunition of the commercial companies. The trial at the National Matches fully bore out expectations as indicated by preliminary tests. Every shooting record has been broken, and broken badly. As an example, the previous record for firing at one thousand yards was 26 consecutive bulls-eyes. It now stands at 76 consecutive bulls-eyes. Records at other ranges have increased proportionately. In fact results depend only on the skill and endurance of the marksman, as the ammunition will continue to shoot steadily into the center of the bulls-eye, practically without limit.

Rock Island Arsenal Notes

Recuperator Building. The new Recuperator Building, known as shop "R," is rapidly nearing completion and will probably be accepted from the contractors in the near future. The building has been erected for the purpose of providing one self-contained machine shop unit to be devoted entirely to the manufacture of recuperators.

The structure consists of one four-story re-inforced concrete building facing on Main Avenue at a point immediately west of Shop "M." On the south, or rear side, of the concrete building has been erected a structural steel shed with corrugated iron roofing which houses four crane-ways. The concrete section is 227 feet 7½ inches long and 86 feet 3 inches wide, the steel section is 206 feet 3 inches long and 194 feet 7½ inches wide. The four floors in the concrete section were designed for the following loadings:

First or ground floor not limited.
Second floor, 250 pounds per square foot.
Third floor, 200 pounds per square foot.
Fourth floor, 150 pounds per square foot.
Roof, 40 pounds per square foot.

Test loads were recently applied to three of the floors of double the above amounts without any cracks developing in the concrete and with practically no deflections in the floor slabs. The concrete building is of the flat slab type of construction with columns spaced on 20 foot centers both directions. Column heads are mushroomed into drop panels. The concrete building is covered with a Barrett specification roof on which a 20 year bonded guarantee has been secured. Toilet rooms, 20 feet square, are provided near the middle of the concrete section on each floor. At each end of the concrete section has been installed a Warner Electric Freight Elevator of 10,000 pounds capacity with a speed of 70 feet per minute. A structural steel stair-way is provided at each end of the

New Recuperator Building, Rock Island Arsenal

building adjacent to the elevator shaft. A standard gauge railroad track enters the steel section of the building from the west and extends across the entire north end of the steel section beneath the four crane-ways. The eight cranes, two to each craneway, have a clear height of 20 feet, six of them being of 5-ton capacity, and the other two of 10 and 20-ton capacity respectively.

The concrete portion of the building is being constructed by Chas. Weitz' Sons of Des Moines, Iowa, under a lump sum contract for $221,176.00. The elevators have been installed by the Warner Elevator Mfg. Co. of Cincinnati, Ohio, under a lump sum contract for $18,750.00. Erection of the steel shed and installation of plumbing, steamfitting and electrical work in the concrete section, have been done by purchase and hire under the direction of the construction and maintenance department of the Arsenal and supervised by the Construction Service of the Quartermaster Corps. The estimated cost of the entire project is $450,000.00.

New Pack Howitzer. Study drawings for a new pack howitzer have been received at this Arsenal from the Office of the Chief of Ordnance. Detail drawings and a wooden model are to be completed and approved before the manufacture of a pilot carriage is undertaken.

This howitzer will be known as the 75 mm. Pack Howitzer, Model of 1922E. The estimated total weight in firing position is 825 pounds. It is divided into four pack loads for transportation on mules. The separate loads are: howitzer, sleigh and recuperator, trail, and wheels and axle.

The new design has greater stability in firing than the Pack Howitzer, Model of 1920. The ballistics are identical with the former howitzer. A helical spring equilibrator replaces the spiral spring equilibrator of the model of 1921

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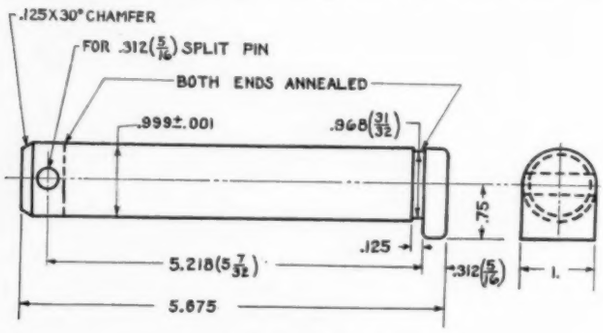
howitzer. The trails are made somewhat shorter, and the quick release locks are simplified.

A modified Puteaux type recoil mechanism which has a constant length recoil is used. The outstanding feature of this design is the use of the recuperator to increase the weight of recoiling parts and thus reduce the firing stresses on the carriage.

Motor Carriage. Study drawings for a motor carriage designed to mount the 4.7-inch Gun or the 155 mm. Howitzer, Model of 1920E, have been received at this Arsenal for detailing and the manufacture of a pilot carriage.

This motor carriage is equipped with a 150 H.P. Sterling, Half-V, four cylinder motor. A Holt type track which has



Track Pin for Artillery Tractor

the truck and supporting rollers, idlers and drive sprockets cushioned with double rubber inserts, is used on this carriage.

The motor carriage is capable of a road speed of approximately 15 miles per hour, and has three speeds forward and one reverse.

Manufacture of Track Link Pins. Competitive bids were asked for a considerable number of track link pins for the 5-ton Artillery Tractor, Model of 1917. Although this track pin is a comparatively simple article, several different routes and estimates, were made to determine the most economical manner in which they could be manufactured.

The order was received and the pins placed under manufacture at an approximate cost of 52 cents per pin. This cost was later considered excessive so a further study was made of the method of manufacture. This study disclosed the fact that the head of the pin as shown in the sketch could be forged to size. New dies were made to forge the head which proved satisfactory after slight modification.

The pins were made of carbon steel S. A. E. specification No. 1020. Round bar stock 1.062 inch diameter was used and was cut to the length of 6.25 inches for forging by means of shears. The following is the route of operations for manufacturing this pin:

1. Forge.
   Note: Forging dies will forge the head of the pin to complete drawing size. One man forges the heads on 1,200 pieces per day.
2. Mill to length using two standard milling machine vises to hold the rough pieces.
   Note: One man finishes approximately 1,200 pieces per day.
3. Center ends.
   Note: One man centers approximately 1,000 pieces per day.
4. Face inside of head, cut recess and chamber.
   Note: One man performs this operation on approximately 450 pieces per day. In this operation the fin left from forging is removed when finishing the undersurface of the head.
5. Rough grind .999 to 1.015 inch diameter.
   Note: One man rough grinds approximately 660 pieces per day.
6. Drill split pin holes.
   Note: A drill press is used for this operation which has four spindles working independently and having automatic stops and automatic feeds. A jig is used under each spindle for holding the pins. One man drills approximately 2,500 pieces per day.
7. Heat treat.
   Note: The heat treatment given these pins is as follows:
   Carbonize at 1650° F. for eight hours;
   Cool in pots;
   Oil quench at 1425° F. to 1450° F. for thirty minutes to one hour;
   Sceleroscope test 70;
   Draw in lead pot the thickness of the head on one end and ⅝-inch back from the opposite end.
8. Clean centers.
9. Finish grind.
   Note: One man finish grinds approximately 550 pieces per day.

The work at this Arsenal is not run on a piece work basis but it was found that by adjusting the press to a certain speed 1,200 pins per day could be forged by one man. Using this as a basis, arrangements were made so that the machine shop finishes 1,200 pins per day.

The approximate cost per pin of machining the pieces is 10.3 cents which makes an approximate total cost of 29 cents per pin.

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